ENVIRONMENTAL ASSESSMENT

SPACE SHUTTLE PAYLOADS AND PAYLOAD OPERATIONS FOR THE SIXTH SPACE SHUTTLE LAUNCH (STS-6)

Richard H. Ott
Manager
STS Flight Assessments

Mail Code MCB-7

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF SPACE TRANSPORTATION OPERATIONS
WASHINGTON, D.C. 20546

Telephone: AC 202-755-7472

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ABSTRACT

The sixth flight of the Space Shuttle (STS-6) with a crew of four astronauts is currently scheduled for March, 1983, from Kennedy Space Center, Florida. This flight represents the initial flight of the Shuttle Orbiter Challenger and the first use of the light-weight Solid Rocket Boosters and External Tank. Also, STS-6 will launch the first Shuttle-transported Inertial Upper Stage (IUS). The primary purpose of the STS-6 mission is the delivery of the initial Tracking and Data Relay Satellite (TDRS-A) and the IUS needed to transport it to geosynchronous equatorial orbit from the Shuttle's low orbit. Secondary STS-6 mission objectives are: to carry and operate seven research payloads which will be returned to Earth at Edwards AFB, California, at the conclusion of the mission; and to conduct tests and collect technical information on Shuttle vehicle systems and supporting equipment.

For normal operations, the only adverse long-term environmental impact from these payload programs will be the addition of the IUS propulsion stages and the ultimately abandoned TDRS-A spacecraft to the population of space debris. While there is concern over the accumulation of space debris, the risk is chiefly collision with unmanned spacecraft and not to the Earth's population or environment. This risk is currently considered acceptable in return for the benefits of greatly increased tracking and data reception capability. There are no significant near-term adverse environmental impacts from the normal operations of any of the payloads. Any environmental consequences of STS launches and accidents are local and temporary and are described in the Final Environmental Impact Statement for the Space Shuttle Program. The results of this assessment support a **Finding of No Significant Impact.**

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1.0 SUMMARY AND CONCLUSIONS

1.1 Proposed Action

The sixth flight of the Space Shuttle (STS-6) with a crew of four astronauts is currently scheduled for March, 1983 from Kennedy Space Center, Florida. This flight represents the initial flight of the Shuttle Orbiter Challenger and the first use of the light-weight Solid Rocket Boosters and External Tank. Also, STS-6 will launch the first Shuttle-transported Inertial Upper Stage (IUS). The primary purpose of the STS-6 mission is to deliver the initial Tracking and Data Relay Satellite (TDRS-A), together with the Inertial Upper Stage (IUS)—needed to transport the TDRS-A to geosynchronous equatorial orbit from the Shuttle's low orbit. Secondary STS-6 mission objectives are: (1) to carry and operate seven research payloads which will be returned to Earth at Edwards Air Force Base, California, upon conclusion of the flight; and (2) conduct tests and collect technical information on Shuttle vehicle systems and supporting equipment.

The Tracking and Data Relay Satellite will initiate a major improvement in NASA's tracking and data relay capabilities. The improved capabilities are needed for NASA and other government spacecraft operations, and the support of future manned mission activity. Three TDRS geosynchronous orbit satellites are planned to be launched by 1984 to support NASA's Tracking and Data Relay Satellite System (TDRSS). Once operational with two TDRS satellites in position (the third is an on-orbit spare), the TDRSS will significantly increase the time available for transmission of data to and from orbiting satellites/spacecraft and the ground. The time available is increased because of the satellite/spacecraft transmission of data directly to the orbiting TDRS and subsequent relay to one ground station located at White Sands, New Mexico. This improved data transmission capability will increase the value of many spacecraft, as well as providing increased safety for the Space Shuttle crew. The transition to TDRSS will permit NASA to phase out ten existing ground stations around the world. The estimated net change in employment at NASA ground stations is a decrease of approximately 100 employees.

The TDRSS is being developed for NASA under a lease arrangement by the Space Communications Company (Spacecom), a jointly-owned subsidiary of Western Union Space Company, Inc., Fairchild Industries, and Continental Telephone Company. Under this arrangement, NASA will lease the service from Spacecom, who purchases the spacecraft from the manufacturers and STS Launch Services from NASA.

The TDRS spacecraft is manufactured by TRW, Inc., and the Boeing Company builds the Inertial Upper Stage (IUS). The masses of the TDRS and IUS are approximately 2300 kg and 14,800 kg, respectively. When integrated and installed in the Shuttle's payload bay they occupy 63 m^3, or about 20 percent of the total volume available. Two solid rocket motors are used by the IUS. They contain a total of approximately 12,000 kg of hydroxl-terminated polybutadiene (HTPB)-based solid propellant. The IUS also carries 112 kg of hydrazine propellant for reaction control. The TDRS carries 605 kg of hydrazine propellant to provide attitude control and station keeping for its planned 10-year life on orbit. The transport of these propellants on the Shuttle presents the largest payload contribution to the risk of possible loss of the Shuttle vehicle and crew as well as adverse environmental effects. Rigorous NASA and DOD safety procedures are applied to the STS and its payloads to preclude risk of catastrophic accidents to the public.

Seven research payloads are classified as either Get-Away Special (GAS) payloads, or as Mid-Deck payloads. Three small self-contained research payloads (Get-Away Specials) will be located in the Shuttle's payload bay. These payloads do not use Shuttle utilities (e.g., power, etc.) and the only attention required by the Shuttle's crew is to turn them on and off by remote control. GAS payloads are being flown on the Shuttle as part of a NASA program intended to encourage new uses of space. Payloads are currently limited to a volume of 0.15 m^3 or 5 ft^3. The three GAS payloads planned for STS-6 are: (1) Crystal Growth of Artificial Snow, (2) Seed Experiment Payloads, and (3) Project Scenic Fast.

The Crystal Growth of Artificial Snow experiment is sponsored by the Asahi Shimbun Company of Japan and will examine growth of snowflakes under zero-gravity conditions. The Asahi Shimbun Company is a major Japanese newspaper which is sponsoring this experiment as the result of a competition for readers who proposed experiments which could be flown on the Shuttle within the constraints for Get-Away Special payloads.

The Seed Experiment Payload is sponsored by the George W. Park Seed Company to expose packaged seeds of many common vegetables and flowers to the space environment. After return to Earth, tests for seed coat integrity, germination, dormancy, increased mutation rate, and vigor or performance will indicate the best packaging method for space transportation of seeds. The test-flown seeds will be compared with control seeds held at Kennedy Space Center and at the company.

Project Scenic Fast is sponsored by the United States Air Force Academy and contains six different student experiments. These are: (a) Metal Beam Joiner to demonstrate the soldering of two brass beams under zero-gravity conditions; (b) Immiscible Alloy to determine whether tin spiked with gallium (23 grams) will exhibit improved conductivity when the two elements are melted together in a zero-gravity environment; (c) Foam Metal will produce a sample of lead foamed by sodium bicarbonate in an evacuated glass tube; (d) Crystal Purification will test the effectiveness of the zone refining method of purification in zero-gravity using an 8-cm rod of lead-tin solder sealed in a glass tube; (e) Electroplating will determine how evenly copper plating is deposited on a copper rod in zero-gravity; and (f) Effects on a Micro-organism will determine the effects of weightlessness and space radiation on the development of non-pathogenic micro-organisms (Sarcena Lutea).

Four Mid-Deck research payloads will be located within the crew cabin. These payloads use Shuttle utilities and require crew attention while the payload is active. These payloads which are either sponsored or co-sponsored by NASA are the Monodisperse Latex Reactor (MLR), the Continuous Flow Electrophoresis System (CFES), the Night-Day Optical Sensor of Lightning (NOSL), and Shuttle GLOW.

The Monodisperse Latex Reactor (MLR) will carry about 400 ml of a water-latex solution. The purpose of this experiment is to react this solution so that small, very uniformly spherical particles of latex are formed in the zero-gravity environment. These spheres will be used later as laboratory standard to measure pore size in membranes. The understanding of pore size effects on the permeability of membranes is expected to lead to economic applications, since many valuable separations of mixtures and solutions can be accomplished with a better understanding of membrane properties.

The Continuous Flow Electrophoresis System (CFES) has as its objective the determination of the effectiveness of electrophoresis methods in zero-gravity. Electrophoresis techniques are used to separate and concentrate biochemical compounds by utilizing slight differences in the compounds' electrical properties. The CFES experiment is intended to provide information about the feasibility of developing a pharmaceutical manufacturing and purification system.

The Night-Day Optical Sensor of Lightning (NOSL) is designed to observe and record data from electrical discharges in the atmosphere, especially thunderstorms. The information is expected to lead to a better understanding of electrical processes in storms and to prediction of their effects.

The Shuttle GLOW experiment is designed to obtain information on the glow which surrounds the Shuttle while in orbit. This glow could interfere with sensitive optical instruments such as telescopes, which will be flown on future Shuttle missions. It is currently uncertain whether the glow is due to the residual atmosphere, or to outgassing from the Shuttle, or to a combination of these possibilities. The information to be gathered will assist in determining the cause of this glow and may lead to a method of controlling the glow.

The seven basic scientific payloads (GAS and Mid-Deck), to be flown on STS-6 have been determined to not be hazardous, and will not have any impact upon the environment.

STS-6 will also perform various development tests (e.g., space suits). The major purpose of these tests is to provide information for use by the Space Shuttle Program, and is not directly related to the payloads previously discussed. The tests will have no environmental impact.

1.2 Alternatives to the Proposed Action

Possible alternatives to the Shuttle-integrated payloads on STS-6 (the proposed action) are: (1) No Action, and (2) Use of Expendable Launch Vehicles (ELVs).

The No Action Alternative is defined as continuing and possibly expanding the current low capability tracking and data reception methods using existing or new NASA ground stations throughout the world. Ten existing ground stations, requiring additional NASA employment, would need to be retained to maintain the coverage for spacecraft at the current 15 percent level. Additional ground stations would be needed to provide the 85 percent coverage level to be initiated by the proposed action. Since NASA is presently unable to provide coverage in many remote locations (over oceans, etc.) the potential to achieve near world-wide coverage of spacecraft with this method would not be practical. The research experiments could not be accomplished under the No Action Alternative. There is no known way to conduct experiments in the terrestrial environment requiring more than very short periods (2-5 minutes) of weightlessness. The NOSL requires the synoptic view of the Earth which can only be obtained from orbit. The Shuttle Glow experiment is specific to the Shuttle. Thus, the No Action alternative implies higher NASA ground station costs for a limited capability tracking and data acquisition network, and no benefits from the proposed research experiments.

For the Expendable Launch Vehicle (ELV) Alternative, the TDRS would be flown on either of two Titan vehicle configurations. With some modifications, the current TDRS design could be flown on a Titan IIIE/Centaur vehicle. This particular vehicle is no longer in production, having been phased-out in the 1970s. With some extensive modifications to the TDRS, which would have to be reduced in mass by 20 percent, a spacecraft with less capability could be flown on a Titan 34D/IUS vehicle. In either case, substantial additional funding would be required to use either of these vehicles. Use of the Space Shuttle, however, provides an opportunity to check the satellite while it is still in Low Earth Orbit. If it cannot be repaired in orbit, it can be returned to Earth, repaired, and launched again on another flight. ELVs cannot perform this function. While the research payloads have not been designed for use on an ELV or sounding rocket, conceptually, they can be adapted and flown. The Shuttle, however, provides the user with lower costs and a safer return of the experiment to Earth. The ELV would either be the Titan used for the TDRS, or a small ELV such as the Scout. In either case, the vehicle with a reentry and recovery system would be more expensive than if flown on the STS. Given current funding trends, it is doubtful that many of the experiments would be funded if the Shuttle were not available. There are also strong indications that if any of the experiments lead to space-manufactured products, they would be economical only if the Shuttle's return capability is available. Thus, while there are possible alternatives for the proposed action of TDRS launch on the Shuttle, the alternatives for supporting the research payloads are questionable either from the technical or economic grounds.

1.3 Environmental Consequences of the Proposed Action and Alternatives

For the proposed action, the only measurable long-term adverse environmental impact from the normal placement of these payloads is the addition of two expended solid rocket motors on the IUS, and the ultimately abandoned TDRS to an already-large population of manmade space debris. The major concern associated with this debris is an increasing probability of collision with spacecraft. While the current debris accumulation poses little threat to the terrestrial environment, there is a low probability of a collision with an active spacecraft. This collision would likely destroy the spacecraft with its fragments adding to the long-term debris population. If the spacecraft were manned, it is possible that a direct hit by debris would result in the loss of life.

If the TDRS spacecraft were launched by a Titan ELV, the Titan Core II stage would also become part of the space debris population in addition to the spent upper stages. For either alternative, the potential collision risk from their addition to the space debris population is currently considered by NASA to be acceptable to obtain the benefits of the improved tracking and data acquisition capabilities. The net reduction in ground station employment of about 100 is not considered to be a significant adverse socio-economic impact; lower employment costs are a benefit to NASA.

For both TDRS placement alternatives, there is a low probability of a catastropic accident caused either by the major payload or by the launch vehicle. NASA and DOD safety procedures for design and operations will eliminate most of the risk of payload caused accidents. In the case of the Shuttle, such an accident would very likely result in loss of the crew's lives. The Titan is unmanned. Accident consequences have been examined and have been determined to result in only local and temporary effects to the environment. Launch system accidents and detailed descriptions of their potential consequences are provided in the final Environmental Impact Statements for the Space

Shuttle Program and for the Expendable Launch Vehicle Program. The STS-6 payload contribution to potential consequences is considered to be very small when compared to the launch vehicle itself.

The research experiments are intended to be returned to the Earth and will have no interaction with the environment. These experiments have undergone safety reviews to provide as much assurance as possible that both the experiments and their ancillary equipment (such as batteries) cannot fail in a manner which would result in a hazard to the Shuttle mission. No synergistic hazards have been found for these payloads.

For the proposed action and alternatives, ground-based installations are needed. The construction, operation, and maintenance of these installations represents most of the direct impact on the human environment. For launch of TDRS by either the Shuttle or Titan, the ground station will be the same. For the No Action Alternative, many additional stations would be needed to provide coverage equivalent to the TDRSS. Resource use would be the lowest for launch of the payloads on ELVs, and the all ground-based system would be the highest.

The short-term temporary environmental impact of the ELV launches would be less than one Space Shuttle launch in terms of noise and rocket-exhaust effluents. For the No Action Alternative, ground-based tracking and data relay system would have a larger impact on the terrestrial environment than a space-based system. This increased impact, however, would be dispersed geographically.

1.4 Recommendation

The Shuttle Launch of the payloads is the currently preferred alternative to achieve improved tracking and data relay services for NASA space missions and for the conduct of research using the space environment. A FINDING OF NO SIGNIFICANT IMPACT for launching the STS-6 payloads is recommended.

2.0 PURPOSE AND NEED

The STS-6 Launch has two purposes: (1) to place in orbit the initial space relay satellite TDRS-A for NASA's Tracking and Data Relay Satellite System (TDRSS); and (2) to conduct a variety of space research experiments. The TDRS-A will initiate a new, cost-effective telecommunications network for NASA's space operations having a significant increase in coverage (85 percent versus 15 percent presently). The research experiments respond to a need in our society to gain more information about materials and processes which may provide advances in technology. Some specific mission activities will provide technical information about STS equipment for use in the STS program.

The TDRS-A spacecraft is the first in a series of three spacecraft (two operational and one on-orbit spare). These spacecraft will be the space segments of a data relay network which will provide the ability to receive signals from spacecraft and Shuttles at a single ground station. The Tracking and Data Relay Satellites will be located in geosynchronous orbit positions such that they can see spacecraft in all Earth-orbital positions except for a small region at low altitudes above the Indian Ocean and Subcontinent. Reconfiguring the design and repositioning the three spacecraft or establishing a ground-station in this area would permit coverage of this blind spot, but such coverage is not considered economically desirable at the present time. The TDRSS is being established for two fundamental reasons: (1) NASA projects greatly increased demand to handle data and tracking information from spacecraft and the Shuttle missions, and (2) the TDRSS reduces the costs associated with servicing this increased demand. The TDRSS allows NASA to close or transfer to other agencies ten ground stations while opening only one new ground station. While the net decrease in current employment is relatively small, estimated to be about 100 people, the TDRSS eliminates the need to establish and maintain a large number of stations needed to supply equivalent services. Thus, while NASA may not achieve a major cost reduction through the TDRSS, significant new costs are avoided.

Research is also viewed as an economic driving force. Shuttle launch and return of experiments makes certain space research economically possible. Space research proposed for the Shuttle cannot be conducted on the ground because it needs a microgravity environment. Also, if this research leads to applications, the Shuttle's return capability is needed to make economic use of the product on Earth. The research payloads for this launch respond to a generalized goal of advancing knowledge and technology.

The scheduled research payloads will conduct experiments in properties of materials, the effects of the space environment on biological systems, and interactions of the Shuttle Orbiter with the space environment. A detailed description of the seven scheduled payloads as well as the TDRS is given in the following section. One of the research payloads, sponsored by the USAF Academy contains several individual experiments and serves an educational purpose as well as a research function. Of the seven research payloads, three are sponsored by non-governmental organizations and represent implementation of U.S. Government policies to encourage research in the space environment by non-governmental organizations.

3.0 DESCRIPTION OF THE STS-6 PAYLOADS, THEIR OPERATIONS, AND IMPORTANT ALTERNATIVES

This section provides a description of the proposed action (NASA/JSC, 1982a) and its important alternatives. The proposed action is to launch, via the Space Shuttle:

- The first Tracking and Data Relay Satellite (TDRS-A)
- Seven Research Payloads
  - Three small Get-Away Special (GAS) payloads located in the Shuttle's cargo bay
    - Crystal Growth of Artificial Snow
    - Seed Experiment Payload
    - Project Scenic Fast (Six Student Experiments)
  - Four experiments located in the Crew's Cabin (Mid-Deck Experiments)
    - Continuous Flow Electrophoresis System (CFES)
    - Monodisperse Latex Reactor (MLR)
    - Night-Day Optical Sensor of Lightning (NOSL)
    - Shuttle Glow Experiment (GLOW)
- Shuttle development test equipment and Shuttle ancillary equipment for testing purposes (e.g., space suits).

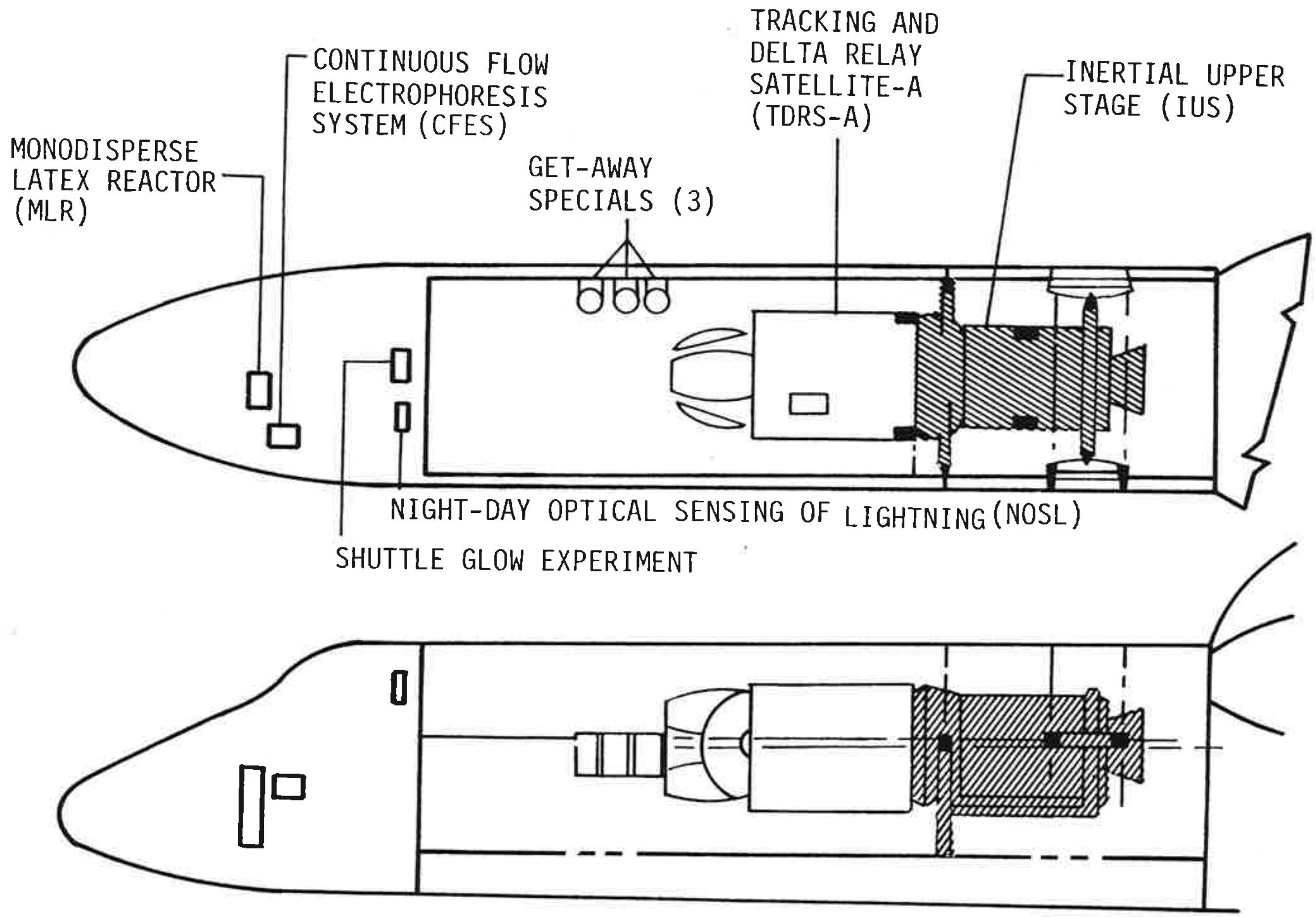
This assessment concentrates on the TDRS-A and research payloads. The flight test activity is described in the Final Environmental Impact Statement for the Space Shuttle Program (NASA/HQ, 1978).

In addition to Shuttle launch of the operational payloads, other alternatives are: (1) use of Titan Class Expendable Launch Vehicles (ELVs) and (2) No Action, which is defined here as retaining and possibly expanding the existing ground-based network of tracking and data reception stations. The research payloads could not be undertaken under the No Action Alternative because terrestrial methods do not provide the necessary uniform low-gravity environment or synoptic view available from orbital altitudes.

3.1 Proposed Action: Space Shuttle Launch of the Payloads

The proposed action is the launch of the TDRS-A and several small research payloads. If the research payloads are not ready at flight-time, they may be rescheduled and put on a later flight; other payloads may be substituted. Figure 1 illustrates the position of the payloads within the Shuttle.

The TDRS is being manufactured by the TRW Defense and Space Systems Group of Redondo Beach, CA for the Space Communications Company (Spacecom) and will be operated for NASA under a lease agreement. The TDRS will be launched from the Shuttle into Geosynchronous Equatorial Orbit at approximately 35,800 km by an Inertial Upper Stage manufactured by the Boeing Company, Renton, WA (see Boeing, 1982). The TDRS will operate on the S($\sim$2.2 Gigahertz) and K($\sim$14Ghz) bands (NASA/HQ, 1983).



SOURCE: NASA/JSC, 1982a

FIGURE 1. PAYLOAD ARRANGEMENT FOR STS-6

The research payloads for the STS-6 launch are divided into two major categories. In one category, three unrelated and relatively small Get-Away Special (GAS) canister payloads will be flown in the Space Shuttle's payload bay. In another category, four research payloads will occupy positions in the Mid-Deck of the Shuttle crew's cabin.

The following detailed descriptions are divided into two sections: general information on the TDRS system and specific information on the TDRS to be launched on STS-6; and description of the research payloads.

3.1.1 Description of the Tracking and Data Relay Satellite System (TDRSS)

The near-Earth orbit tracking and data acquisition activities of NASA are currently evolving from a network of ground-based tracking stations (Spaceflight Tracking and Data Network or STDN) to a system of geosynchronous orbit data relay satellites. This new approach to providing these important services is officially known as the Tracking and Data Relay Satellite System or TDRSS. TDRSS was conceived by NASA as the most efficient means of providing continuing service to the user spacecraft community in an era of rapidly increasing technological demands. The cost implications of maintaining and improving a large number of ground stations in overseas locations were a major factor behind development of this new system.

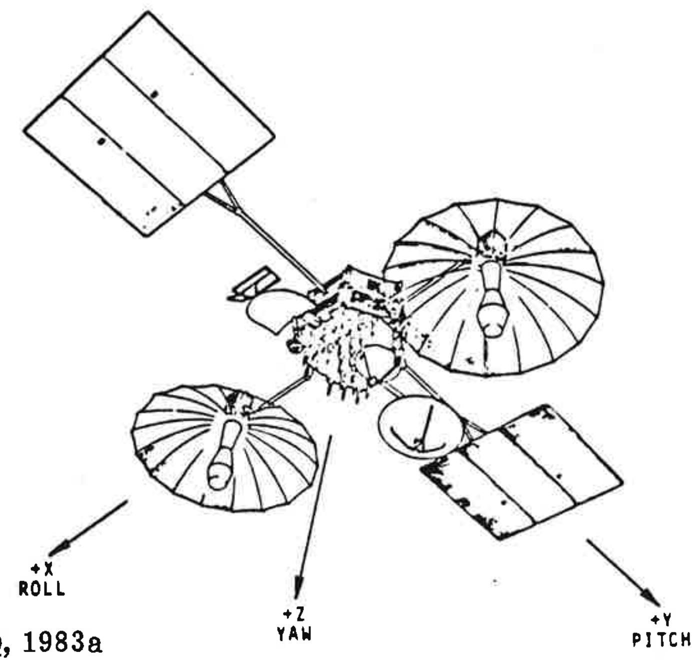
The space segment of the TDRSS consists of two geosynchronous Tracking and Data Relay Satellites (TDRS) located at 41 and 171 degrees west longitude and a spare spacecraft located at 79 degrees west longitude. The orbital positions of the two primary TDRSs have been optimized to provide maximum coverage of user satellite orbits, while simultaneously allowing a single ground station at White Sands, NM to control the satellites. This configuration enables TDRSS to provide orbital coverage of at least 85 percent as compared to the 15 percent currently available from STDN. TDRSS is also capable of handling significantly higher user data rates than have been previously available. The design of the TDRSS was structured to meet the projected service demands on the NASA network for the next ten years, the expected life of the spacecraft.

The actual implementation of the TDRSS has been handled through a lease arrangement with a privately-held company known as Space Communications Company (Spacecom). Spacecom is a jointly owned subsidiary of Western Union Space Communication, Inc., Fairchild Industries, and Continental Telephone Company. The NASA lease covers a period of ten years during which service will be provided by Spacecom in accordance with the provisions of their contract. The system being leased by NASA requires Spacecom to purchase both the spacecraft and launch services as well as to provide the ground terminal located at White Sands, NM. The following subsection provides additional information on the TDRSS elements. A detailed description of the TDRSS is available in the Mission Operation Report for the Tracking and Data Relay Satellite, TDRS-A, Office of Space Tracking and Data Systems, Report No. T-313-83-01 (NASA/HQ, 1983).

3.1.1.1 TDRSS Elements

Principal elements of the TDRSS include the spacecraft, the ground terminal, and TDRSS services, as well as the launch system and operational activities (Shuttle/IUS). Each of these items will be discussed briefly in the following paragraphs.

Spacecraft (TDRS). The TDRS is a body stabilized (three-axis), momentum-biased configuration with Sun-oriented solar panels. Figure 2 illustrates the TDRS as it appears when deployed in geosynchronous orbit. At the beginning of its orbital lifetime, the spacecraft weighs approximately 2124 kg. The on-orbit TDRS measures 17.4 meters from tip-to-tip of the deployed solar panels by 14.2 m from outer edge-to-outer edge of the deployed single access antennas. The TDRS is oriented during operation so that the yaw axis (Z) is pointing at the Earth.



Source: NASA/HQ, 1983a

FIGURE 2. TDRS ON-ORBIT CONFIGURATION

The spacecraft is transported on the Shuttle and IUS with the appendages in a stowed position. The resulting configuration is roughly hexagonal in shape with a diameter of 2.97 m and a length of 5.87 m. Figure 1 depicts the TDRS as installed in the cargo bay of the STS together with the Inertial Upper Stage (IUS). The launch weight of the spacecraft includes the TDRS/IUS adapter and is about 2273 kg, of which 603 kg is hydrazine propellant for attitude control and stationkeeping during the expected 10-year life of the spacecraft.

The TDRS is built in three distinct modules: (1) an equipment module that houses the attitude control; electrical power; propulsion; and telemetry, tracking, and command subsystems; (2) a payload module that contains elements of the telecommunications subsystem such as the IF processing and frequency generation equipment; and (3) an antenna module that supports the deployable and fixed antennas, the multiple access array, and the remainder of the telecommunications hardware.

Ground Terminal (WSGT). The White Sands Ground Terminal supports this mission by providing traffic-carrying ground equipment and associated services which connect the NASA user traffic interface and the orbiting TDRSs. In addition to supporting user link data-relay functions, the ground terminal monitors and maintains the space segment.

The ground terminal consists of:

- Three 18-meter K-band (13.7 to 15.2 Gigahertz (GHz)) user-traffic antennas, an S-band (2.2 to 2.3 Ghz) antenna, a K-band and an S-band simulation/verification antenna, and a K-band and an S-band antenna for measurement of axial ratio. These include appropriate switching, multiplexing, and control center equipment.
- A central, colocated operations building with associated radio frequency, signal processing, data processing, and control center equipment.
- Calibration, simulation, and verification support equipment.
- NASA communications, control, and user equipment.
- The associated support facility and personnel.

Because long-term reliability and adaptability of the TDRSS is of primary importance, the ground segment performs many functions which are ordinarily found in the space segment of a satellite system. This both minimizes the complexity of the space segment and locates critical functions at the ground, where they may be modified or repaired with the least system perturbation.

The WSGT building also houses the NASA-owned portion of the user traffic interface which is termed the NASA Ground Terminal (NGT). The entire facility is located on the Johnson Space Center's test facility at White Sands, New Mexico. The overall WSGT configuration is depicted in Figure 3. The facility at White Sands is significantly larger than other tracking facilities. The physical characteristics of the operations building include: (1) a total area, 2,694 m^2, including a technical area, 742 m^2, Government area, 464 m^2, and 1486 m^2 of support areas; and (2) power requirement 2,000 kilowatts.

The NASA Ground Terminal (NGT) is the interface for communications between the TDRSS WSGT (colocated with it) and remote user elements and NASA facilities. The NGT is a major element in the multilink path of communications between the spacecraft and user's project operations control center. Initially, Goddard Space Flight Center (GSFC) and Johnson Space Center (JSC) will be the primary remote facilities connected to the NGT. GSFC will primarily be using the TDRSS for operations with spacecraft, while JSC's use for the TDRSS will primarily be for Shuttle operations.

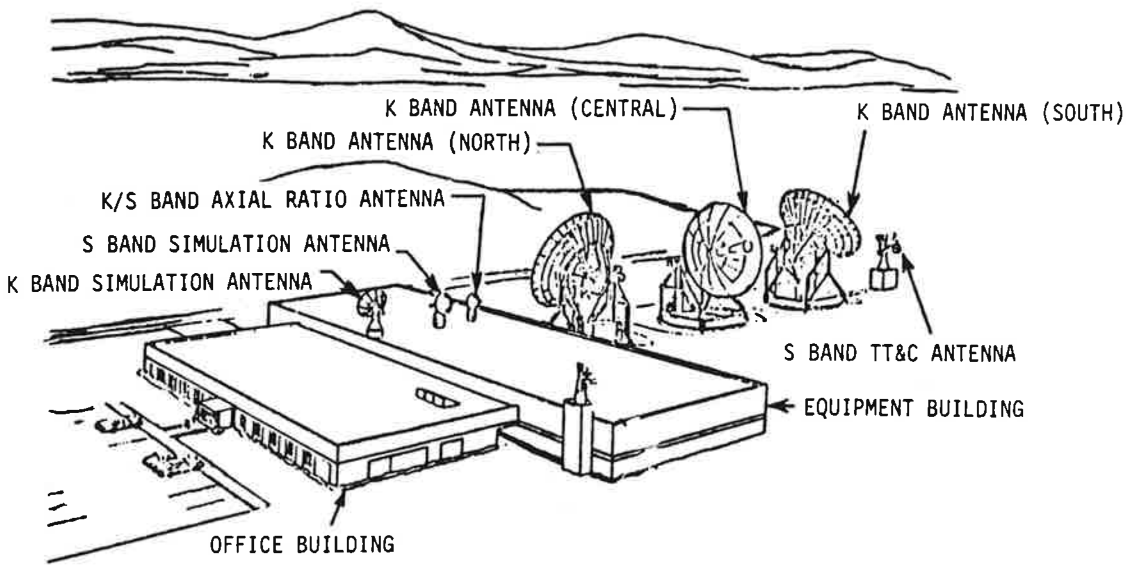


FIGURE 3. WHITE SANDS GROUND TERMINAL CONFIGURATION

TDRSS Services

The TDRSS services are divided into three categories: user forward link and return link communications services, tracking services, and simulation/verification services.

The user forward and return link services are of three types: multiple access (MA), S-band single access (SSA), and K-band single access (KSA). The S-band MA services can support up to 2 MA forward links of up to 10 kilobits per second (kbps) each, and up to 20 MA return links at user data rates ranging from 1 to 50 kbps. SSA service provides simultaneous coverage of two users per TDRS with telemetry rates between 1 kbps and 6 Megabits per second (Mbps). As many as four simultaneous SSA users can be handled with the two operational TDRSs. SSA service equipment also provides support to Shuttle spacecraft using Shuttle-unique modulation parameters. KSA service provides simultaneous coverage of two users per TDRS (four total for two TDRSs) with telemetry rates between 1 kbps and 300 Mbps.

The tracking services for a two-satellite TDRS constellation include 10 one-way doppler measurements (of velocity), 2 MA two-way range and doppler measurements, and 4 SA two-way range and doppler measurements.

TDRSS simulation/verification services are employed to simulate a user spacecraft or to demonstrate TDRSS performance. These services can be provided for 2 KSA channels and 1 each MA, SSA, Shuttle S-band, and Shuttle K-band channels.

User frequency assignments fall in either S-band (2.2 to 2.3 GHz) or Ku-band (13.7 to 15.2 GHz), as shown in Figure 4. A spacecraft's center frequency is user defined, subject to GSFC approval.

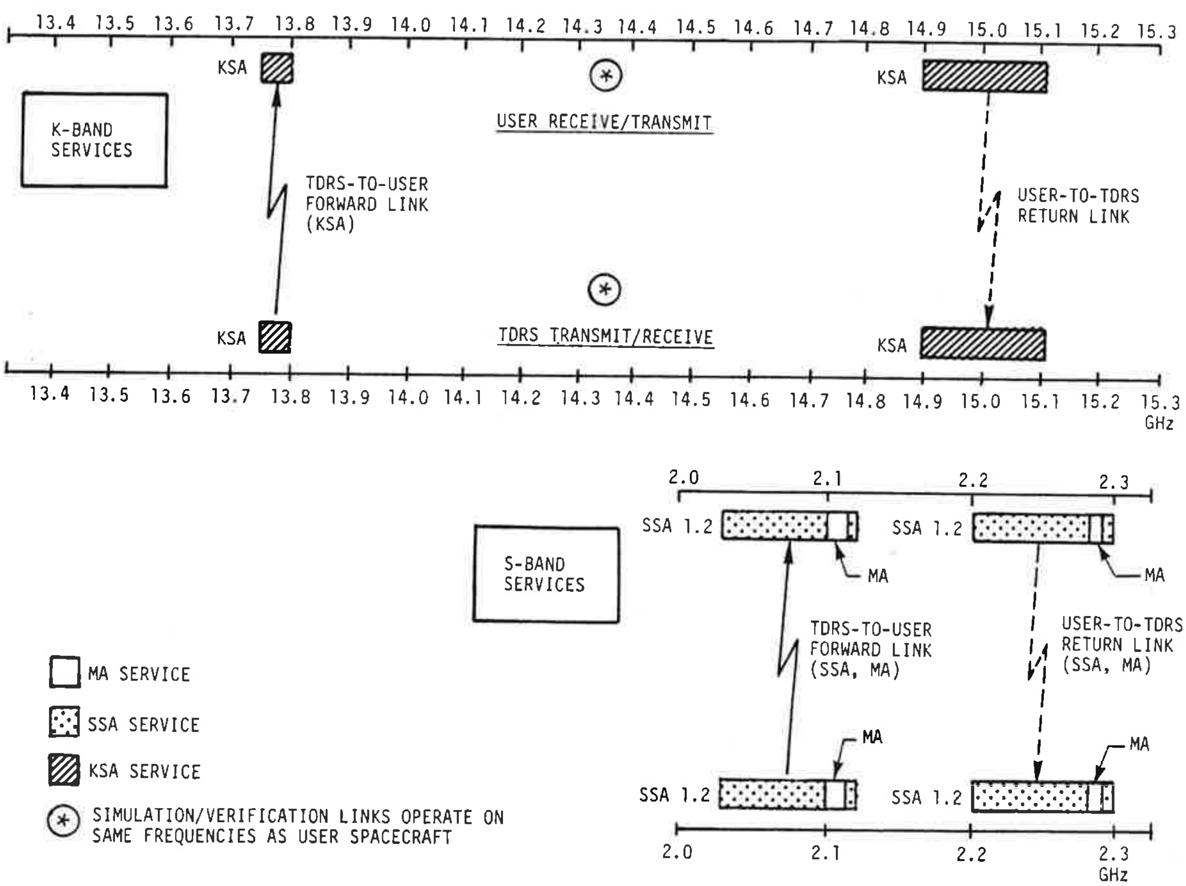


FIGURE 4. USER SERVICES FREQUENCY PLAN

TDRS-A Launch System and Operational Activities. The first step in establishing the space segment of the TDRSS will be the launch of TDRS-A together with the IUS needed to transport it from the Shuttle's low Earth orbit to geosynchronous orbit. Following geosynchronous orbit deployment and check-out, TDRS-A will provide limited user support on a best-efforts basis. Full TDRSS service is scheduled to be available 90 days after the launch of TDRS-B. Both TDRS-B and -C will be carried to orbit on future

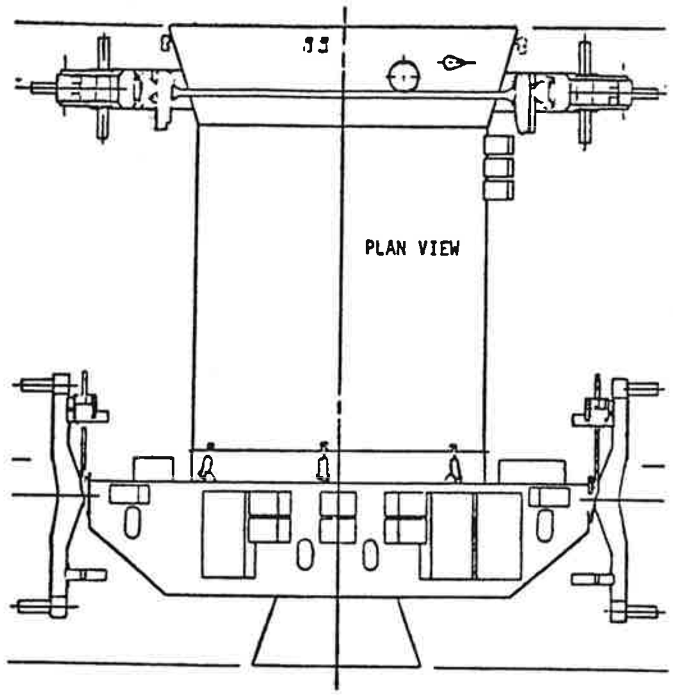
Space Shuttle flights. TDRS-B is currently scheduled for launch on STS-8 in June, 1983 and TDRS-C is manifested for flight on STS-12 in March, 1984. Because of delays in flight readiness of the second Shuttle Orbiter, Challenger, the schedule for the flight may be adjusted.

The Shuttle Orbiter will transport the previously integrated IUS/TDRS-A payload to a low Earth orbit of approximately 284 km and 27 degrees inclination. This integrated payload is then mechanically ejected from the Shuttle Orbiter's payload bay; after a safe distance is achieved, the first of two Solid Rocket Motors (SRMs) is ignited and places the payload into a geosynchronous transfer orbit. Approximately six hours later, the second IUS SRM is used to place the TDRS-A spacecraft in geosynchronous orbit at 35,796 km at a longitude of 54.4 degrees West longitude above the equator. A Reaction Control System (RCS) on the IUS provides direction and velocity corrections during the IUS operations. After the TDRS reaches geosynchronous orbit, the IUS uses its RCS to maneuver away from the TDRS to prevent a later collision. The IUS is then abandoned.

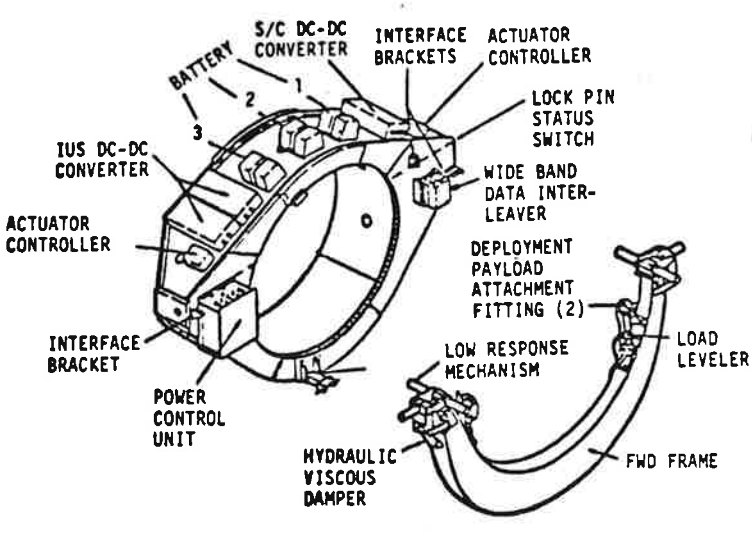
A detailed description of the Space Shuttle and its planned operations are given in Space Shuttle (NASA/JSC, 1976).

IUS. The Inertial Upper Stage was developed by the U.S. Air Force with the Boeing Aerospace Company as prime contractor. The IUS is an integral part of the Space Transportation System and can be launched either from the Space Shuttle bay or by a Titan 34D vehicle. The basic two-stage IUS vehicle (Boeing, 1982) is 5.18 m long and 2.32 m in diameter in the cylindrical section and weighs about 14,772 kg in the Shuttle-launched configuration. The IUS's fundamental elements are two Solid Rocket Motors; an interstage; an equipment support section holding triply redundant avionics for guidance, navigation and control; the Reaction Control System; and an electrical power system. The Solid Rocket Motors, manufactured by the Chemical Systems Division of the United Technologies Corporation, use hydroxl-terminated-polybutadiene (HTPB) based propellants. The mass of the first stage motor is 9,730 kg and the mass of the second stage motor is 2,728 kg. The mass of propellant in both motors is about 12,000 kg. The Reaction Control System provides the thrust needed for attitude control during coasting, roll control during SRM-powered flight, vehicle maneuvers and spacecraft separation maneuvers. The RCS is a blow-down pressurized system having two fuel tanks with 56 kg of hydrazine in each.

The IUS vehicle is shown in Figure 5, together with the airborne support equipment (ASE) which provides the mechanical and electrical interface between the TDRS-A, IUS, and Orbiter. The ASE interface provides mechanical support and electrical services and control while the payload is in the Orbiter bay, provides the ability to elevate the TDRS-A/IUS for its checkout prior to development, and supplies the initial separation velocity of about 0.3 m/sec. to the payload. If the TDRS-A or IUS were not able to complete the checkout successfully, the ASE supports would be lowered into the Orbiter bay for return of the spacecraft to Earth for repair and later reflight. Additional technical information on the IUS can be found in the Mission Operation Report for TDRS-A (NASA/HQ, 1983).



Source: Boeing, 1982



Source: NASA, 1983

FIGURE 5. INERTIAL UPPER STAGE AND AIRBORNE SUPPORT EQUIPMENT

3.1.2 Research Payloads

The research payloads are divided into two major categories: The Get-Away Special (GAS) canisters carried in the Shuttle's payload bay and payloads which have most of their equipment located in the crew's compartment (Mid-Deck Experiments).

3.1.2.1 "Get-Away Special" (GAS) Payloads

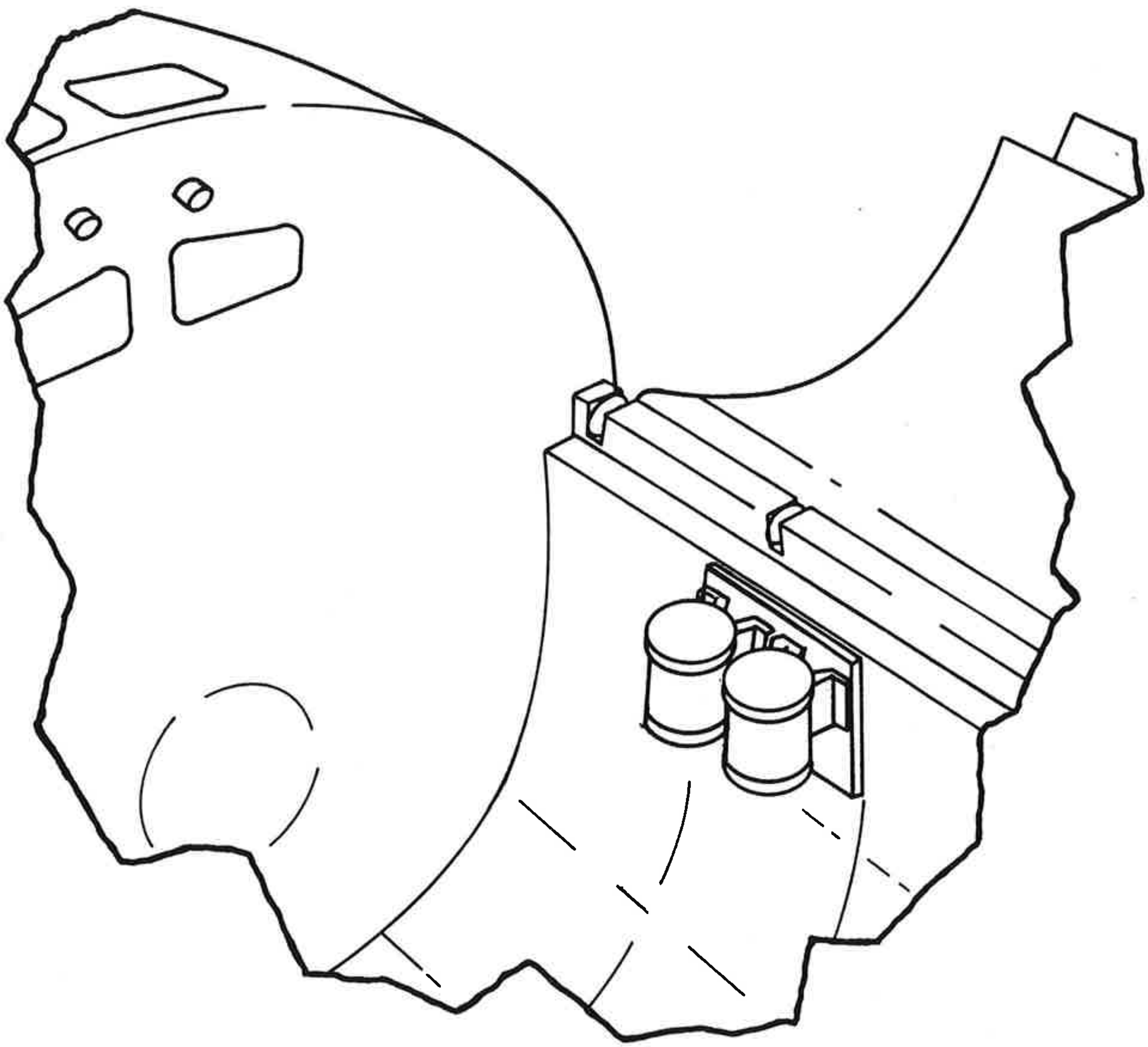
Get-Away Special (GAS) payloads are carried in canisters in the Shuttle's payload bay at special low charge rates. This is intended to stimulate new uses of the space environment by new user organizations. GAS payloads do not use Shuttle utilities, such as electrical power, and crew attention to them is minimal (usually limited to turning them on and off by remote control from the cabin). A typical GAS container and its location in the payload bay are shown in Figure 6. These containers are currently limited in size to 0.15 m^3 or 5 cubic feet (NASA/GSFC, 1979).

STS-6 is scheduled to carry three GAS payloads:

(1) Crystal Growth of Artificial Snow is sponsored by the Asahi Shimbun Company of Japan (Asahi Shimbun, 1982), and will examine growth of snowflakes under zero-gravity conditions. The Asahi Shimbun Company is a major Japanese newspaper which is sponsoring this experiment as the result of a competition for readers who proposed experiments which could be flown on the Shuttle within constraints for Get-Away Special Payloads. Snow crystals will be made in two small cold chambers and the process of the growth of the crystals will be recorded on video tape through charge coupled device cameras. The experiment will be repeated four times and will use self-contained batteries.

(2) Seed Experiment Payload is being sponsored by the Geo. W. Park Seed Co., Inc. (Alston, J. A., 1982) and will expose packaged seeds of many common vegetables and flowers to the space environment so that later tests on Earth for seed coat integrity, germination, dormancy, increased mutation rate, and vigor or performance will indicate the best packaging method for space transportation of seeds. The test seed will be compared to controls held at the company and at KSC. Approximately 46 varieties of vegetable and flower seeds will be placed in two types of bags: a) dacron polyester sown with polyester thread and b) polyethelene covered aluminum foil pouches supplied by the American Can Company. The experiment is completely passive.

(3) Project Scenic Fast is sponsored by the Department of Astronautics of the United States Air Force Academy and contains six different cadet-designed experiments (USAF Academy, 1982). All the experiments use self-contained battery power. The first four are controlled by an internal sequencer which is initiated by the Shuttle crew. The last two are separately initiated by the Shuttle crew. The six experiments are:



Source: NASA/GSFC, 1979

FIGURE 6. TYPICAL GAS INSTALLATION

(a) Metal Beam Joiner, mass 2.6 kg, which will demonstrate the soldering of two brass beams in zero-gravity conditions.

(b) Immiscable Alloy, mass 2.3 kg, which will determine whether tin spiked with gallium (23 grams total) will exhibit improved conductivity when the two elements are melted together in a zero-gravity environment.

(c) Foam Metal, mass 3.45 kg, will form a sample of lead foamed by a small amount of sodium bicarbonate when heated in an evacuated glass tube for five minutes.

(d) Crystal Purification, mass 2.9 kg, will test the effectiveness of the zone refining method of purification in zero-gravity using an 8 cm long rod of tin-lead (80-20 mixture) solder sealed in a glass tube. The tube is wrapped by a small heating coil which will travel slowly along the tube. A narrow successive band of the solder will melt and float impurities to the end.

(e) Electroplating, mass 6.3 kg, will prepare a sample for later determination of how evenly copper plating is deposited on a copper rod in zero-gravity. The experiment uses copper electrodes and a copper sulfate electrolyte.

(f) Effects on a Micro-organism, mass 9.1 kg, will expose samples of normally non-pathogenic microorganisms, Sarcena Lutea, to a test of the effects of weightlessness and space radiation on the microorganism development. Four tubes will be flown in the experiment and two of these will be shielded from radiation by a lead box. At the start of the experiment a motor will pull nylon cords through a nutrient solution to initiate growth from a freeze-dried state. After 24 hours, mineral oil will be pumped into the tubes to halt the microorganism growth.

These payloads contain materials with relatively low risk and which are toxic only if ingested.

3.1.2.2 Mid-Deck Experiments

Four research experiments will have most or all of their equipment located in the Mid-Deck of the crew's compartment. These experiments are usually more complex than the GAS payloads and require somewhat more of the crew's attention as well as the use of Shuttle utilities while they are active. These Mid-Deck payloads are:

(1) The Monodisperse Latex Reactor (MLR), developed by the Polymer Science Institute for Marshall Space Flight Center, will carry about 400 ml of a water-latex solution (NASA/MSFC, 1981). The object of the experiment is to react this solution so that small, very uniformly spherical particles of latex are formed in the zero-gravity environment. These spheres will then be used as a standard to measure pore size in

membranes. The understanding of pore size effects on the permeability of membranes is expected to lead to economic applications since many economically valuable separations of mixtures and/or solutions can be accomplished with a better understanding of membrane properties. The MLR is illustrated in Figure 7.

(2) The Continuous Flow Electrophoresis System (CFES) is co-sponsored by the Johnson and Johnson Company (pharmaceuticals and healthcare products) and NASA (Richman, 1982). The object of this experiment is to determine the effectiveness of electrophoresis methods in zero-gravity. Electrophoresis techniques employ slight differences in electrical properties to separate biochemical compounds which are difficult to separate by other means. This CFES experiment is intended to be a forerunner of a pharmaceutical manufacturing and purification system which, if necessary, may be located permanently on-orbit. The CFES is illustrated in Figure 8.

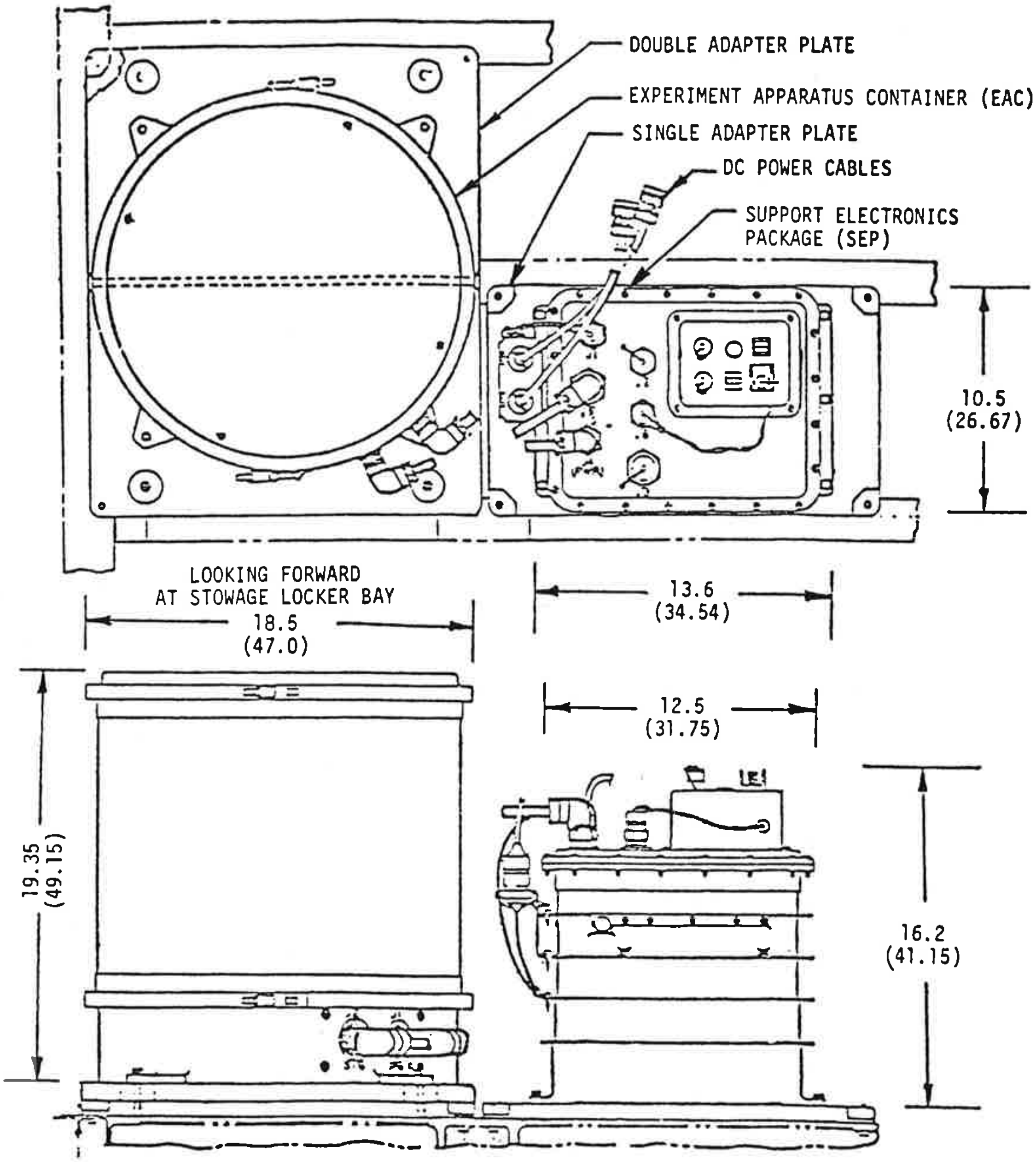
(3) The Night-Day Optical Sensor of Lightning (NOSL) is designed to observe and record data from electrical discharges in the atmosphere, especially thunderstorms (NASA/JSC, 1982b). The information is expected to lead to a better understanding of the electrical process in storms and to the prediction of their effects. This experiment consists of sensors connected to a recorder and a small camera. This experiment was also flown on the fourth STS launch and may be reflown again to gather additional information.

(4) The GLOW experiment is designed to obtain information on the glow which surrounds the Shuttle while on orbit (NASA/JSC, 1982c). This glow is presently considered to have the potential to interfere with sensitive optical instruments such as telescopes which are planned for flight on later missions. It is presently uncertain whether the glow is due to the residual atmosphere or due to outgassing from the Shuttle or to a combination of these effects. The information to be gathered will assist in determining the cause and may lead to the ability to control the effect. The GLOW experiment consists of small electronics instruments.

A review of the seven research experiments found only materials which are not considered hazardous under normal operating conditions.

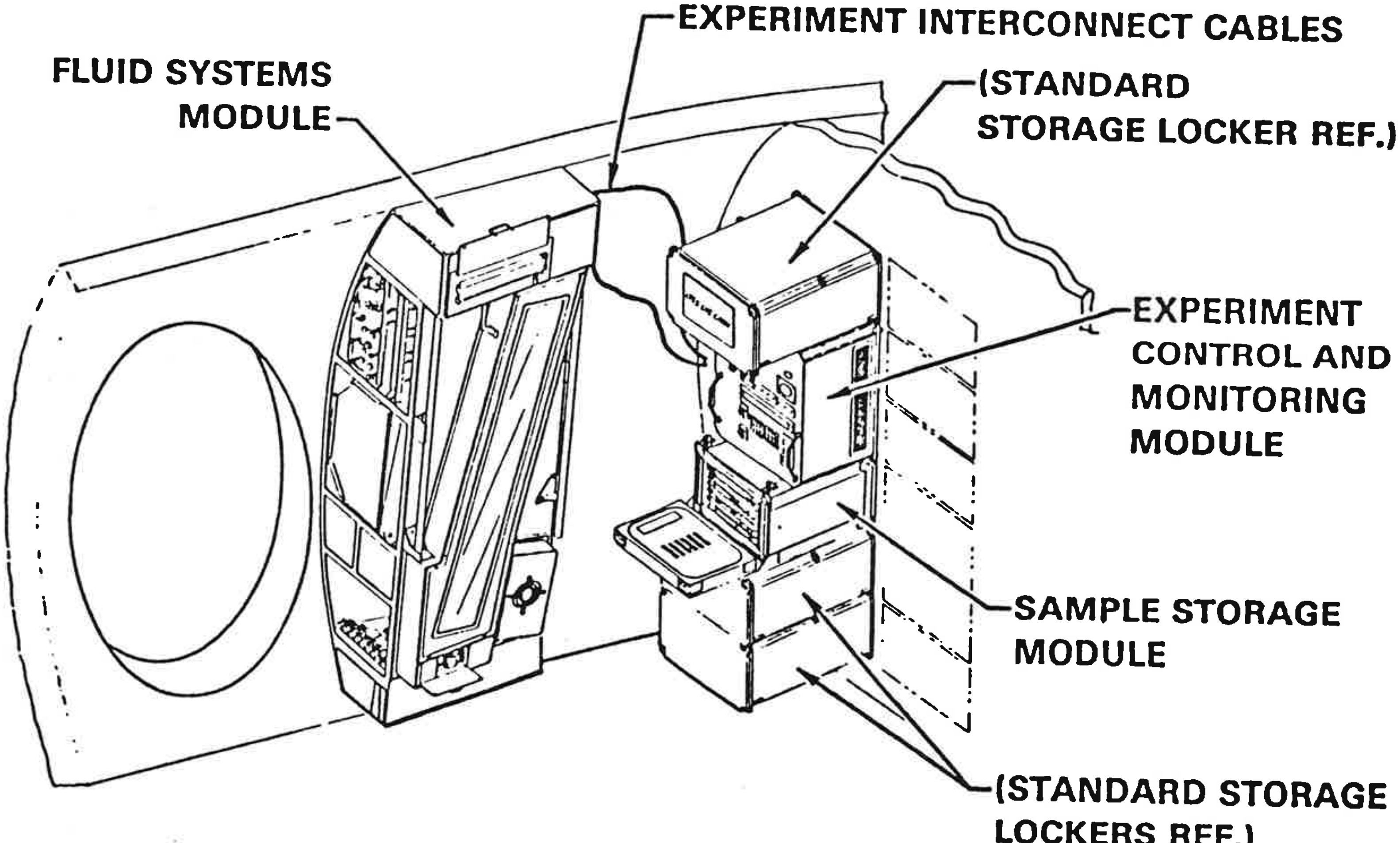
3.2 Description of the No Action Alternative (Terrestrial Equivalents)

There are two different types of operational payloads on the STS-6 mission; the TDRS, a unique form of communications satellite, and the research payloads. Many TDRSS functions could be accomplished by the existing ground station network, but for the research payloads, there is no terrestrial equivalent to flying the payloads in space. Available terrestrial methods do not provide the zero-gravity environment required by most of these payloads. The NOSL experiment also requires the synoptic view provided by spaceflight, and the GLOW experiment is intended to provide information specific to the Shuttle Orbiter.



Source: NASA/MSFC, 1981

FIGURE 7. MONODISPERSE LATEX REACTOR (MLR) EXPERIMENT



SOURCE: Richman, D., 1982

FIGURE 8. CONTINUOUS FLOW ELECTROPHORESIS SYSTEM (CFES)

Many TDRSS functions could be accomplished by a ground station network. Many of the stations which could be used are in the process of being closed or transferred out of NASA control in anticipation of the availability of TDRSS, but the current stations would provide only 15 percent of global coverage in contrast to the 85 percent provided by TDRSS. Thus a terrestrial network equivalent to TDRSS would require a substantial number of new stations with significant additional costs.

If it were decided that the user spacecraft and Space Shuttle could be supported from currently available ground stations, much of the No Action Alternative would consist of not closing (or reopening) the ten ground stations in use at this time. These stations as well as the surviving ground stations would receive satellite and Shuttle data and tracking information for local processing and retransmission to the spacecraft mission centers in the continental U.S. Much of the information would be transmitted to the ultimate users via existing and future communications satellites in geosynchronous orbit. Terrestrial communications methods such as submarine cables and microwave relay towers could be used to transmit data to users in the U.S., but these would result in higher costs than for satellite transmission.

3.3 Use of Expendable Launch Vehicles for STS-6 Payloads

In addition to Shuttle launch of the payloads, it is also possible to launch them with Expendable Launch Vehicles. For the TDRS-A spacecraft, there are two alternative Titan vehicle configurations which can be adopted. The existing design for the TDRS spacecraft has a weight of 2272 kg and, if modifications were made to the spacecraft, it could be launched on a Titan III E/Centaur (T3E/C) vehicle (NASA-DOD, 1972). The T3E/C vehicle would have enough mass transport performance capability that the research payloads and a suitable reentry bus might also be carried along. While none of the research payloads has been designed to fly on an ELV, it is expected that most of them could be redesigned. The major problem would be to control their volume requirements to fit within available ELV shroud designs. The T3E/C Vehicle, however, is no longer in production, and would have a substantial non-recurring cost to restore launch facilities and equipment to operational status.

The other Titan vehicle configuration adaptable to this mission is the Titan 34D/IUS (T34D/IUS) which is in production but has payload capability to geosynchronous orbit of about 1900 kg, or about 20 percent less than the current TDRS design. For the T34D/IUS, the spacecraft would have to be redesigned to weigh less and thus would be a less capable spacecraft. There would be no excess lift capability on the vehicle to carry research payloads; these could fly on vehicles such as the Scout.

Use of either of these vehicles would incur additional design and/or restoration costs above those for vehicle production and launch. These would include restoration of the T3E/C capability or redesign of the TDRS spacecraft to fly on the T34D/IUS; and the design, manufacture, and testing of a reentry bus for research experiments to fly on a Titan vehicle and/or on a smaller vehicle such as the Scout. The magnitude of these design and/or restoration costs is expected to be somewhat less than the current cost differential between developmentally mature ELVs to launch the payloads and the current cost to launch them on the Shuttle. In addition, there would be a significant delay in the proposed actions and the shift of business to the ELVs would delay progress in learning to use the Shuttle. Thus, if the TDRS were to be launched by a Titan vehicle, the near-term costs to NASA might be less than for the Shuttle. However, this condition would not apply to the research payloads. Three of the research payloads are sponsored by non-government organizations and are economically constrained. They are currently scheduled to fly on the Shuttle for reduced fees (e.g. a maximum of $10,000 for a GAS payload) and probably would not be supported if full current costs of either the Shuttle or an ELV were imposed. The costs to NASA of launching the research payloads on the Shuttle, moreover, are reasonably considered to be marginal. Thus, while use of ELVs for the research payloads is technically feasible, the current charge policy to the non-government users is such that they would strongly prefer to use the Shuttle. The Shuttle's capability to return the payload to the user without undergoing the stresses associated with an ELV launch and reentry is also desired. If these research payloads lead to an application requiring space processing, there are strong indications that the Shuttle's capability to return payloads to the Earth would be needed to make these applications economical.

4.0 ENVIRONMENTAL IMPACTS OF PROPOSED ACTION AND ALTERNATIVES

4.1 Summary

This section summarizes the possible physical and socioeconomic effects of the payloads as well as their terrestrial equivalents under the No Action Alternative. The impacts of each of the three alternatives (Shuttle Launch of the Payloads, No Action, and ELV Launch) are assessed individually. Table 1 summarizes and compares their environmental effects.

For all of the STS-6 payloads or their alternatives, there are few measurable adverse effects, and these are considered to be more than offset by the benefits achieved from these payloads. The only measurable long-term adverse environmental effect of normal operations will be caused by abandonment of expended propulsion stages used by the TDRS launch and the ultimate abandonment of the TDRS itself. This effect will occur whether the Shuttle or an expendable launch vehicle is used. Temporary environmental effects will occur due to launch activities—launch noise and possibly some spotting of launch site vegetation from hydrogen chloride in the exhaust from solid rocket motors used in either the Shuttle or ELVs for the two spaceborne alternatives. Longer-term effects will occur from occupancy of the TDRS ground station, but these are considered minor and would occur from any other use of the site by the same number of people. The ground-based alternative would have similar occupancy effects at installations located around the world.

The research payloads are expected to have only indirect environmental effects because they do not interact with the environment. These will be due to occupancy effects of the institutions sponsoring and manufacturing the payloads.

The only predictable socioeconomic effect of the TDRS payload will be a decrease of about 100 employees on the current total of the NASA Space Tracking and Data Network. In absolute numbers, the net reduction is not large. If the No Action Alternative of ground stations were selected, there would be an increase of several hundred employees to give minimally acceptable ground-based coverage, and possibly several thousand to provide complete ground-based coverage equivalent to that provided by TDRS. For the Research Payloads on STS-6, no major socioeconomic consequences can be predicted because the research is technically oriented. Research is considered to be an economic driving force and economic benefits are expected from spaceborne research, but it is difficult to predict which projects are critical and which provide only supportive information. Thus, while economic benefits are sought, no confident predictions can be made for specific payloads on STS-6.

4.2 Space Shuttle Launch of the Payloads

This subsection provides a detailed assessment of the environmental effects of the Proposed Action, the Space Shuttle launch of the TDRS and the seven research payloads.

TABLE 1. SUMMARY OF ENVIRONMENTAL EFFECTS FOR STS-6 PAYLOADS

	Shuttle Launch of Payloads	No Action (Terrestrial Equivalents)	ELV Launch of Payloads
Air/Water/Land Quality	B- Small impact via launch, ground stations	B- Additional ground stations and operations, microwave relay towers	B Launch effects similar to, but slightly less than Shuttle. Ground stations same as Shuttle.
Noise	C- Concentrated launch, reentry noise	B Dispersed construction noise	C Effects similar to, but slightly less than, Shuttle
Space Quality (Space Debris)	D Addition to Space Debris	A No addition to Space Debris	D Addition to Space Debris about same as for Shuttle
Human Health and Safety	B- Noise and potential for local acid rain (HCl) from launch	B Small impacts	B Effects similar to, but slightly less than, Shuttle
Ecological Resources	B- Impact from launch, ground stations	B- Possible impact from new construction in undeveloped areas	B Launch effects similar to, but slightly less than Shuttle. Ground stations same as Shuttle.
Socioeconomic Impacts	SB+ (TDRS)/SB+ (Research) Long-term benefits from research Near-term benefits from improved space operations	SB (TDRS)/D (Research) No equivalents for research payloads; space operations become more difficult	SB (TDRS)/C (Research) Research not as economical for ELVs. Shift of business for launch contractors.
Resource Use	B- Small on national scale, greater than for ELVs.	B- Resource use larger than for satellite network, small on national scale	B Resource use slightly less than Shuttle.
Accident Consequences	c to f (1) Loss of Shuttle flight crew (2) Loss of payloads (3) Loss of significant amount of data and tracking capability (4) Very small probability of severe, long-term public consequences	d (1) Accidents to workers (2) Possibility for aircraft collision with communications masts (3) Temporary loss of data and tracking capability	d (1) No loss of flight crew possible (2) Loss of payloads (3) Loss of significant amount of data and tracking capability (4) Probability of consequences to public less than for Shuttle (5) Accidents to ground crew (6) Low probability of accidents from stage reentry

SB = Significant Benefit
A = No Effect
B = Small Effect
C = Measurable Adverse Impact
D = Measurable Long-Term Adverse Impact
F = Significant Long-Term Adverse Impact

b = small effect, low probability
c = C with low probability
d = D with low probability
f = F with low probability

4.2.1 Air, Water and Land Quality

The primary direct impact on air, water and land quality from the flight of these payloads comes from the launch of the Shuttle and operation of the White Sands Ground Terminal. A secondary impact comes from the operation of the Kennedy Space Center, and the operations of the contractors who supply the payloads. The KSC and contractor operations for STS-6 represent a small portion of their ongoing activities. Detailed information on the impacts at KSC is given in the Final Environmental Impact Statement (EIS) for the Space Shuttle Program (NASA/HQ, 1973), the Final EIS for Kennedy Space Center (NASA/KSC, 1979), and the Environmental Document for the White Sands Test Facility (WSTF, 1980). The major direct impact on air quality of previous launches has been some spotting of vegetation at KSC from hydrogen chloride exhaust from the Shuttle's Solid Rocket Boosters which has combined with water vapor in the exhaust and atmosphere to form a mist. Atmospheric dispersion models indicate that under most conditions, the exhaust cloud will dissipate without significant effects. Under some meteorological conditions, a launch may have to be delayed until the conditions change. If a launch were made under unfavorable conditions, locally severe acid rain could occur. The unfavorable major local impacts on water and land quality, however, come from the existence of the Kennedy Space Center (KSC) and White Sands Ground Terminal (WSGT) and their occupancy. It is important, however, to note that the existence of KSC and WSGT has allowed protection of the natural state of much of the surrounding area. The level of activity associated with the payloads at KSC, as contrasted to the Shuttle, is minor and occurs over a period of a few months. Activities at the WSGT are ongoing, and the environmental effects are relatively minor and primarily due to human occupancy of the site.

Of the approximately 14,000 total employment (2100 government) located at, or in association with KSC (NASA/KSC, 1983), only about 500 are currently associated with payloads, and many have only an indirect involvement. Most people working on the TDRS spacecraft and the other payloads are drawn from the electronics industry. This industry presents a relatively low burden on air, water and land quality in general and the payloads represent a very small part of the industry. The rest of the people who work on non-electronic parts of the payloads, such as the IUS, are associated with the aerospace industry which presents a slightly larger, but still relatively low air, water, and land burden in comparison to basic materials industries. The amounts of material (about 16,000 kg) in the payloads and IUS represent a miniscule fraction of the demand for the types of materials used and, thus, do not create any additional environmental effects from their use. The U.S. Air Force developed the IUS as part of their contribution toward operation of the Space Transportation System (STS/Space Shuttle). In a Candidate Environmental Impact Statement prepared by the USAF for the IUS program (USAF, 1977), they assessed the overall environmental effects of both development and operation. The conclusion reached was that any probable adverse impacts from the IUS program's ground operations would be of a local and temporary nature.

The White Sands Ground Terminal which will relay the signals to and from the TDRS will have only a small effect on the local air, water and land quality. This station is located in a desert area of New Mexico and thus will have some impact on water use. The construction impacts are largely over, and are the same as for most types of construction, and do not present any undue impacts. Indirect emissions, such as those from power plants, are small in relation to those generated for other purposes in the area served. There are no direct emissions significantly effecting air, water and land quality, and indirect operating emissions are due to human occupancy of the area. Only minor and chiefly indirect emissions can be attributed to the research payloads. Examples of these would be the travel and building-occupancy emissions from the individuals working with the payloads.

4.2.2 Noise

The major noise associated with the placement of payloads comes from the launch and return of the Space Shuttle. These noise levels are temporary and are described in the KSC and Shuttle Program EISs (NASA/HQ, 1978; NASA/KSC, 1979). The noise can be expected to briefly disturb wildlife near the launch site, but no significant effects are expected. A personnel exclusion zone prevents humans from being exposed to hazardous noise levels. No significant noise is associated with the STS-6 payloads themselves.

4.2.3 Space Quality (Space Debris)

Since the first orbital launch by the USSR in 1957, thousands of launches, primarily by the U.S. and U.S.S.R., have placed satellites, expended launch vehicle stages, and associated components in Earth orbit. Many of these have returned to Earth, but approximately 5,000 items greater than 10 cm in diameter are still in orbit and are tracked and cataloged by the U.S. Air Force (Kessler, D. J., 1978, 1981). These objects range from fragments of exploded stages through old spacecraft to expended stages themselves. They present a very low direct hazard to the public since even the larger items usually break up and burn up before ground impact. Because of high orbital velocities, a collision with an active spacecraft is likely to result in the destruction of that spacecraft and the generation of additional fragments of debris. A provision has recently been made to control the growth of space debris, specifically by having liquid propellant stages expel all propellants and pressurized systems after separation from their payloads and before abandonment. This prevents unused propellants from later causing an explosion which scatters large numbers of small fragments. There is some concern that the current population is almost large enough that it can become self-sustaining through the collision-fragmentation process. At and below current population densities, the population tends to be self-clearing as the drag of the residual atmosphere causes medium altitude objects to drift to lower altitudes and low altitude objects to reenter and burn up. About 10 percent, or 500, of the trackable objects are in geosynchronous orbit. In addition to the abandoned stages, the propellant exhaust products have been detected from ground observations for several hours after stage ignition. To date there has been no detectable effect on payloads from rocket propellant exhausts because they disperse in space. There is some concern that residual exhaust products, and especially the fine powder (mostly Al_2O_3) from solid rocket motor exhaust, may degrade or damage delicate sensors such as telescope mirrors.

The placement and use of the TDRS-A will leave one expended IUS solid rocket motor case in geosynchronous transfer orbit with parameters of 282 x 35.785 km altitude and 26.6 degrees inclination to the equator. The second stage and the rest of the IUS will be abandoned near geosynchronous orbit after a burn of the stage's attitude control system to prevent collision with the deployed TDRS-A. The TDRS-A will be placed in geosynchronous equatorial orbit at 35,785 km altitude and 54 degrees west indirect operating emissions are due to human occupancy of the area. Only minor and chiefly indirect emissions can be attributed to the research payloads. Examples of these would be the travel and building-occupancy emissions from the individuals working with the payloads.

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The maximum collision probability from members of the debris population occurs between 600 km and 1500 km altitude, the region repeatedly traversed by the first IUS stage. Here, the probability of collision is currently about 10^{-5} per square meter of spacecraft cross-section per year (Kessler, 1981). Thus, a spacecraft in this region with a collision cross section of 10 m^2, about that of the IUS stage or the undeployed TDRS spacecraft, would have a probability of collision of about 0.001 over a typical 10 year life of a spacecraft.

The addition of the three major items of debris is expected to increase the overall probability of collision in direct proportion to the increase in debris population. The launch of the TDRS-A will leave the first stage in an orbit which crosses the 600 km to 1500 km region where about 80 percent, or 4,000, of the estimated 5,000 items of detectable debris reside (Kessler, 1981). This will cause a population increase in this region of about 0.025 percent. Thus the probability of collision would increase from about 1.0×10^{-5} per square meter to about $1.00025 \times 10^{-5}/m^2$. The current population in geosynchronous orbits is much lower than at 600 to 1500 km. Kessler et al indicate that the debris and potential future debris is about 10 percent of that at lower altitudes or about 500 objects. The proposed action will place two objects in geosynchronous orbit (the IUS 2nd Stage and the TDRS-A), resulting in a population increase of 0.4 percent. The probability of collision in geosynchronous orbits for a spacecraft with a radius of 6 m or about that of the deployed TDRS-A, is about 3×10^{-7} per year or 2.65×10^{-9} per square meter of spacecraft collision cross-section per year (Chobotov, 1981). The proposed action would raise this to about 3.01×10^{-7} per year or 2.66×10^{-9} per m^2 per year, a factor of 4,000 lower risk than at 600 to 1500 km. Because of these relatively small increases in risk, the benefits of improved tracking and data relay capability are considered by NASA to be an acceptable trade-off.

The research payloads are intended for return to the Earth and will make no addition to the space debris problem. Objects inadvertently released from the Shuttle cargo bay are usually small and light. Because of the relatively low operating altitude of the Shuttle, these will experience the drag of the upper atmosphere and reenter and burn up within a short time. These objects can reenter the atmosphere anywhere between 28.5 degrees north or south of the equator (NASA/JSC, 1982a). No ground impact damage is likely, and the objects are unlikely to disrupt space operations. The spent IUS first stage is expected eventually to reenter and burn up in the atmosphere (USAF, 1977).

4.2.4 Human Health

There are three main areas for human health concern: the Space Shuttle, the payloads themselves, and the ground station used with the TDRS. Space Shuttle health concerns are addressed in that Program's EIS (NASA/HQ, 1978). The payloads and ground station have little or no capacity to impact human health under normal operating conditions. Consequences of potential accidents are discussed in Section 4.2.8.

4.2.5 Ecological Resources

There are few or no consequences to ecological resources from the payloads and their operations because there is little coupling with the biological environment. From the standpoint that TDRS reduces the need for ground stations, the effects are positive. The identifiable impacts are from the Shuttle launch at KSC and the largely completed White Sands Ground Terminal. Details are discussed in their respective environmental documents (NASA/HQ, 1978; WSTF, 1980). The Shuttle impacts are chiefly temporary, local damage due to acid precipitation, noise, and from low probability accidents. The impact of the WSGT is chiefly due to the construction and occupancy of the facility. The WSGT is a relatively small facility in a large desert. The facility is not intended to be a tourist attraction so that the desert environment will not be subjected to undue occupancy pressures. While desert environments can be sensitive to occupancy pressures, the staffing level of approximately 300 at WSGT is not high enough to exert significant pressures beyond the immediate site.

4.2.6 Socioeconomic Impacts

The socioeconomic impacts of the payloads have several aspects: (1) the manufacture and launch of the payloads; (2) the conduct of research; and (3) the operation of the TDRS and the closing of ground stations which are no longer needed.

The U.S. has retained a leading position in the development, manufacture of space technology, and the launch of payloads. Space applications missions are a source of desirable jobs and a positive factor in the balance of international payments. Although this specific launch has only a little foreign sponsorship, it can be viewed as part of a process needed to maintain and improve the U.S. competitive position in an increasingly competitive environment.

For the research payloads, no detailed socioeconomic prediction can be made. Research is an integral and usually beneficial aspect of man's society. Those experimental payloads are intended to lead to scientific advances. If they are successful, the specific results may lead to benefits in the economy or society. The USAF Academy and Asahi Shimbun experiments can also be viewed as an educational as well as scientific endeavor.

The TDRS payload, however, has a specific intended socioeconomic impact of reducing the number of ground stations and personnel needed to operate them. In addition to improving the U.S. capability to track and relay data from spacecraft, the U.S. also hopes to reduce personnel and facilities operations costs needed to maintain the existing ground tracking and data relay network. While the White Sands Ground Terminal's personnel (300 people) and their costs are being assumed via the TDRSS lease agreement, ten of seventeen ground stations have been or are being closed or transferred to other agencies. Detailed NASA projections indicate that these closings will result in a reduction of about 400 people employed on NASA tasks. Of these, about 300 are U.S. citizens or holding jobs which would be available to U.S. citizens and 100 are foreign nationals (Bastedo, W. G., 1982). Of the approximately 400 jobs to be terminated under NASA programs, about 300 are likely to be transferred to other agencies, chiefly Department of Defense or NOAA programs. The Chilean Government may take over the Santiago, Chile, facility to provide services to others, such as the Japanese, who desire use of a South American facility. While the contractor (Bendix) has a good record of redeploying individuals to other jobs under its contracts, it is possible that some of the people from the closed facilities will not receive replacement employment. Others may not wish to move from their current locations.

Shared commercial use of TDRS-A and -B is highly unlikely so that there will be a barrier between the NASA use of the payload and potential commercial use of these two satellites. Accordingly, socioeconomic consequences other than the shift in NASA employment is unlikely. The economic advantage of TDRS is not only the rather small reduction in current employment, but also the avoidance of higher staff levels needed for a ground-based system.

4.2.7 Resource Use

For Shuttle placement of the payloads, the launch itself constitutes the greatest direct use of resources. The ground station construction and operations represent a smaller, but ongoing use of resources; the payloads represent a small and one-time use of resources. The Shuttle's primary resource use consists of 1,721 metric tons (MT) of rocket propellants, an expendable fuel tank and its fuel, and use of deluge water on the pad. The Shuttle Orbiter and Solid Rocket Boosters (SRBs) are recovered for later refurbishment and reuse. The resource requirements for the payloads with a total mass of about 16 MT (the SRMs account for about 12.5 MT) are small in comparison with the Shuttle's materials requirements (Boeing, 1982; NASA/JSC, 1976). Generic estimating techniques (Rice, 1978) indicate that the payloads represent an energy investment of about 15 x 10^9 kJ in comparison to an energy investment of about 1500 x 10^9 kJ for Shuttle launch. The energy investment for the Shuttle launch is approximately the total annual energy requirement for about 3,800 midwestern homes. Except for the SRB's propellant binder, polybutadiene acrylonitrile (PBAN), and propellant oxidizer, ammonium perchlorate (AP), the Shuttle launches and their payloads do not have a significant effect on national resource demand. The primary use of PBAN and AP is in rocket propellants (NASA/MSFC, 1977).

Accordingly, Shuttle launch of STS-6 payloads is not considered to have a significant effect on resource consumption.

Resource consumption for ELV launch of the payloads would require approximately two-thirds that of Shuttle launch (Rice 1978). The no action alternative of ground-based stations would result in the highest level of materials and energy use. Personnel and facility support requirements for electricity and fuel would be the major cause of this high level of resource demand.

4.2.8 Accidents

Accidents and their consequences can be grouped into three major areas: (1) the Shuttle and Shuttle operations, (2) the payload and related operations, and (3) the White Sands Ground Terminal and its operations.

Potential accidents and their consequences are covered in considerable detail in the Shuttle Program EIS (NASA/HQ, 1978) and are considered only briefly here and chiefly in relation to the interaction between the Shuttle and the payloads. The major risk of an accident is a fire or crash of the Shuttle, either in flight or on the launch pad. This could be initiated either by a failure in a Shuttle system or by a failure in a payload system or component. For the STS-6 mission, the major source of payload risk to the mission is a low probability of ignition of the propellants on the TDRS-A and IUS.

Because of the potential for catastrophic accidents to the Shuttle from a variety of sources including propellants, all payloads undergo safety reviews specified by NASA policy and implementing directives (NASA/HQ, 1980; NASA/JSC, 1979). These reviews require design and test procedures which keep the probability of accidents as low as possible, and which limit the consequences of any accidents which do happen. These reviews concentrate special attention on, but are not limited to, stored energy (such as propellants and batteries) and hazardous materials. Under severe accident scenarios (NASA/HQ, 1978), these could precipitate or participate in catastrophic on-pad or in-flight accidents, but represent only a small portion of the same or similar propellants which are used in a Shuttle launch. The payload propellants on STS-6 would thus present only a minor contribution to a locally severe launch accident. Among the potential consequences of the accidents are destruction of the Shuttle, its crew, and payloads; fire/explosion damage to the local environment; and release of hydrogen chloride (HCl) to the atmosphere. The HCl could combine with atmospheric moisture to form acid mist or rain and cause further local harm to humans, animals, and vegetation.

In other accident scenarios, such as emergency landings with few STS propellants remaining onboard the Shuttle, the payload propellants would contribute a proportionately larger part of the energy release in a smaller, but still locally catastrophic accident. For an emergency landing from orbit at an airfield where special ventilating and cooling equipment is not available or operational (due either to lack of or break-down of the equipment), the heat generated by reentry would soak back into the payload bay. For the STS-6, the TDRS/IUS payload could overheat and possibly ignite if no action is taken. Because the Shuttle tiles are excellent insulators, the heat soak-back into the bay would take sufficient time to allow ground support to take the necessary precautions if the cooling equipment is available. In the event of a landing in water with the TDRS/IUS on-board, the propellants, especially hydrazine and ammonium perchlorate in the IUS motors could escape into the water and cause temporary local effects to fish. If the water were shallow enough to permit recovery operations, the propellants would likely present no risk to recovery operations. These accidents are low probability and efforts to prevent damage to the Orbiter and the environment are part of NASA's standard operating procedures.

Subsequent launches will place at least two more TDRS satellites in orbit. The third TDRS satellite will serve as an on-orbit spare. Thus, if one of the satellites is lost after launch, no major problems are anticipated. If two or more TDRS satellites fail, the loss of capacity would be significant and would have a major adverse impact on the conduct of U.S. space programs until replacements are launched. With reduced capacity, some valuable spacecraft data could not be collected and the value of the spacecraft would be reduced. Also, the ability to monitor and control spacecraft would be reduced, and this could lead to loss of spacecraft which could otherwise be avoided.

Other payload accidents or malfunctions are unlikely to have disasterous consequences. If electrical or mechanical failures happen to the research payloads, or to the TDRS-A/IUS before it is released from the cargo bay, the payload can be returned to

Earth. This ability is a major advantage of using the Shuttle. The consequences of such failures are economic; the payload has been saved, but the value of the launch services may be lost.

The research payloads are relatively passive and have little capability to cause injury. There is a small probability of an electrical accident which would result in a minor battery explosion, but shielding requirements make it very unlikely that even this would result in injury to humans. For the USAF Academy's GAS experiment with non-pathogenic microbes, it is an extremely unlikely that radiation or other aspects of the space environment could cause a mutation into a pathogenic or economically damaging organism. Most mutations are lethal and lead to lower viability in the affected organism. There is no indication that exposure to the space environment is more likely to cause a viable adverse mutation in the Academy's microbe experiment than many other laboratory procedures. Also, if such a mutation were to occur, the experiment is still under control. The rest of the Shuttle, as well as its payloads, carry a randomly accrued population of microbial species without control. No adverse mutations have been attributed to previous space flights, so risk of adverse consequences from the experiment is considered to be very low.

For all payloads, there is a small probability of occupational accidents. These can occur during ground operations as well as in space and can cause property damage, injury and loss of life. Access to the vacinity of payload operations, extensive training, and safety equipment and procedures are used to limit and control this risk.

The White Sands Ground Terminal can present occupational risks of the type which can occur in most endeavors. During operation of the ground stations, there is also a small potential for microwave radiation to be misdirected into the environment and this may pose a small risk of injury. This potential for exposure usually occurs as a result of abnormal equipment operation and is usually noticed because the radiation is lost before transmission through the antenna. The transmitting antenna is always directed to look through a cleared area toward the satellite and this path is always selected such that the public on the ground is not exposed to hazardous levels of microwave power. If a worker were to be located near the antenna during operation, it is possible that safe exposure level criteria would be violated, but severe exposure is extremely unlikely. Quickly hazardous power densities usually cause noticeable heating of the body, which serves as a warning to turn off power. Equipment is normally shielded to prevent exposure accidents, but dangerous exposures are possible. Brief exposures at sensible heating levels are not hazardous, and are even used as deep heat therapy (diathermy). Hazardous exposure to the public is considered highly unlikely.

The maximum initial output to the TDRS antennas is about 750 watts (NASA/HQ, 1983) and this is spread by the antennas over many square kilometers even though the beam is kept as tight as possible. This results in a peak ground exposure below 10^{-6} milliwatts/cm^2, well below power density levels recognized as safe for long-term exposures. The normally radiated power by ground stations ranges from 2.5 kilowatts to 20 kilowatts with typical ground station power levels in the range of 5 to 8 kilowatts (Stuckly, 1977). The TDRS uplink power levels have been placed under security classification and are not available for inclusion in this assessment. The use of large antennas at the WSGT indicates that the effective radiated power levels will be high. The OSHA safety standards permit an occupational exposure of 10 milliwatts/cm^2 and brief public exposure of 5 mW/cm^2 are tolerated (e.g., microwave oven leakage). Exposures at or below 1 milliwatt/cm^2 are considered in the U.S. to have no long-term effects on mammals (Schwan, 1982).

Calculations by Stuckly (1977) indicate an occupational exposure of 10 mW/cm^2 from a ground station with an 8 kilowatt RF output can occur at 0.46 km. The ground station beam, however, is directed up through a clear area toward the satellite, so that there is little opportunity (balloons, cloth covered aircraft) for the public to receive significant exposures. The off-axis power levels (side lobes) usually decrease to 0.01 of the on-axis values for angles greater than 5 degrees from the axis. Other than at extreme northern latitudes, antennas are pointed more than 10 degrees above the horizon. Ground station design requirements thus preclude most public exposures.

The occupational safety experience at the White Sands Ground Terminal is expected to be analogous to the broadcasting industry which has a better-than-average safety history than the private sector (BLS, 1982).

4.3 No Action (Terrestrial Equivalents)

If the payloads were not launched, the alternative for the TDRS would be the continued use of the ground station network. Some existing ground stations would not be closed, and some stations already closed would be reopened. If the same coverage as for the TDRSS were to be provided, additional stations would be required in foreign countries. Relay of data to the continental U.S. would best be accomplished by communications satellites, but it would be possible to accomplish the data relay by submarine cables and/or ground-based microwave towers. If an all-ground-based system were chosen, additional submarine cables would be required. Locating stations in foreign countries requires diplomatic agreements and, usually, lease payments or other compensation such as a specified level of indigenous employment. Of the ten ground stations which are being closed for the proposed (Shuttle-Launch) activity, seven are located in foreign countries. Since the TDRS system provides near global coverage, additional stations would be needed to provide comparable for low-altitude spacecraft. A station on the Indian subcontinent or on an island in the Indian Ocean would provide coverage at low altitudes beyond that planned for the TDRS system.

For the No Action Alternative, no substitute for the research payloads is possible. The only known potentially adequate terrestrial method of simulating zero-gravity is by aircraft flying a parabolic trajectory. This simulation provides neither the duration required nor, because of the effects of atmospheric turbulence on the aircraft, the uniformity of zero-gravity required for sensitive experiments. Accordingly, the No Action Alternative would require foregoing the benefits of most research in zero-gravity.

4.3.1 Air, Water and Land Quality

The No Action Alternative would avoid the direct near-term and temporary effects on air, water, and land quality associated with the STS-6 Shuttle launch. However, it would not change the long-term effects of operating the Kennedy Space Center. The No Action Alternative would replace temporary local air, water, and land quality effects at KSC with dispersed effects from operating and maintaining an existing or expanded ground station network. Additional effects on land quality would come only from construction of new stations and would be small. Air and water emissions associated with either construction or operation would be small and occur at locations around the globe and over a period of decades. They are unlikely to have any significant effects on the environment away from the immediate site.

4.3.2 Noise

For the No Action Alternative, the temporary noise levels produced by the Shuttle launch and landing would be replaced by minor, local, and temporary noise from ground station activities. Since a major purpose of the TDRS is to support Shuttle operations and spacecraft launched by the Shuttle, the benefit of eliminating the noise from one Shuttle flight is questionable.

4.3.3 Human Health

For normal operation of the ground station network, no human health hazards or issues have been identified. Accidents and their consequences are discussed in Section 4.3.7.

4.3.4 Ecological Resources

Ground stations present few impacts on ecological resources. The greatest effects would be due to construction in previously undeveloped areas. Since many, if not most of these stations already exist, few new consequences are expected. The ecologically significant emissions from ground stations are due to human occupancy and ground stations do not attract much traffic beyond employees. Accordingly, the ground station operations do not present an unusual burden on ecological resources. This burden, however, is a continuing one, in contrast to the Shuttle launch, which has a temporary impact.

4.3.5 Socioeconomic Impact

The No Action Alternative implies the retention and possible expansion of the existing ground network. This default action would retain employment at the current stations and prevent some employment problems for these employees. At least 100 net jobs would be retained (Bastedo, W. G., 1982). The retention of these jobs, however, would have employment costs to the U.S. Government and coverage of Earth-orbital satellites would not be as broad. Thus, the immediate implications of the No Action Alternative for TDRS are predominantly technical.

If the No Action Alternative were interpreted as abandoning the concept of data relay satellites, a form of communications satellite, in favor of a totally ground based network, the implied reduction in the aerospace industrial sector would have serious socioeconomic impacts. The effects on society of reducing both research and technical communications use of space are not easily predicted, but are considered by NASA to be significant and adverse.

4.3.6 Resource Use

If ground stations which are closed or in the process of closing were used in conjunction with commercial satellite relay of data received from the satellites, the future resource requirements for this system would be modest, but larger than for the proposed Shuttle launch of the TDRSS. These ground stations would require additional electronic equipment and electricity as well as habitation consumables (heating fuel, water, etc.), but for the ten existing stations with 50 to 100 personnel per station, the resource requirements for the 500 to 1000 people are not greatly different from those which would be consumed in typical employment of the same number of people. The energy consumption for daily operation of the ground station, however, represents a relatively large use of energy in comparison to a Shuttle launch. The annual per capita energy consumption of the U.S., per NASA employee, and per midwestern U.S. home are all in the range from 3.0 to 4.0 x 10^9 kJ (Rice, 1978). From this range, it is calculated that a ground station with 75 employees (typical range from 50 to 100) represents an annual expenditure of 17 percent of a Shuttle launch. The ten ground stations which would be retained under the no action alternative thus would represent an annual energy expenditure of 170 percent of a Shuttle launch. For the proposed action, three Shuttle launches will provide a more capable system with a life of approximately ten years. Additional stations would require new construction, another source of moderate resource use.

If the No Action Alternative were interpreted to imply that communications satellites were not to be used to relay the data from the ground station to the users, a system for submarine cables and terrestrial microwave relay towers would be required. While some existing transmission systems could be used, the lack of communications satellites would place a burden on existing ground communications systems, so new capacity would be required. Most of this capacity increase would be in submarine cables linking remote parts of the world, but ground-based microwave towers (about 100 at 50 mile average spacing) would be required to transmit the data across the country to NASA centers.

4.3.7 Accidents

Accidents possible for the No Action Alternative are workplace accidents at the existing ground stations and construction accidents at any new ground stations. If the data were not relayed via communication satellite, there would be additional risks from installation of submarine cables and microwave relay towers. The relay towers would present an aircraft collision hazard.

The ground station safety environment is relatively good. The closest analogy for which statistics are collected (BLS, 1982) indicates that radio and television broadcasting has an incident rating much better than the private sector average. Construction of new stations would involve a temporary work accident related risk of about 19.5 incidents per 100 workers per year, about twice the average of the private sector.

Satellite relay of data to the users in the U.S. would be preferred for cost reasons. If ground based transmission were selected, there would be another small source of risk to the public via aircraft collisions with microwave towers. The addition of about

100 communications towers in the U.S. is not believed to represent a significant increase in risk of aircraft accidents. From 1974 through 1978, there were an average of 4.8 collisions per year with electronics towers of all types of which an average of 2.8 per year were fatal accidents (NTSB, 1975-79). The population of broadcast towers, about 6,492 (DOC, 1982), is a major subset of the total population of electronics towers. If the towers were to be built for this alternative, the 100 towers would represent an increase of less than 1.5 percent. Over the ten year life of the TDRS satellite, the use of these towers would lead to an expectation of 0.42 fatal accidents. The probability of a severe Shuttle accident, in contrast, is believed to be less than 0.001. The three Shuttle launches needed for the TDRSS system with satellite lifetimes of about ten years would accordingly have a probability of a fatal accident of about 0.003.

4.4 Use of Expendable Launch Vehicles

Expendable Launch Vehicles (ELVs) are an alternative way of launching the proposed payloads. The TDRS would have two options: (1) redesign the TDRS to a flight weight of about 1900 kg and use the existing Titan 34D with a version of the IUS to fly a slightly less capable spacecraft; (2) restart production of the Titan III E/Centaur which can carry the 2273 kg mass of a modified version of the existing design and have the lift capability to fly some of the research payloads. For either option, there would be significant additional costs. Use of the Titan 34D would require significant expenditures to rework the spacecraft design, and would produce a less capable spacecraft. Use of the Titan III E/Centaur would require a non-recurring effort to restart production and reinstall launch facility equipment for a launch vehicle which was originally used for planetary missions. The cost of either of these options is of the same order of magnitude.

The research payloads have been designed strictly for the Shuttle, but it is considered likely that reasonable modifications would permit them to fly on either the Titan/Centaur as "piggyback" payloads or on a Scout vehicle together with a reentry system to permit recovery of the payloads.

Most experiments are subject to economic constraints. While no direct economic return is expected from the proposed research payloads, the experiments are part of a broad program of space research which is expected to lead to significant economic applications during the coming decade. The cost of the Scout and development of a reentry system is sufficiently high as to preclude the conduct of these experiments if the full launch costs were imposed. ELVs are not likely to provide both the technical and economic requirements for likely future space manufacturing of materials envisioned to follow from this general area of research.

Thus, while there are potential substitutes for the Shuttle launch of the TDRS payload, the substitutes for the research payloads are considered very marginal.

4.4.1 Air, Water and Land Quality

The primary impact on air, water, and land quality from the substitution of either of the ELV options for the Shuttle will be due to the launch of the ELVs. The effects of ELV launches are described in the Environmental Impact Statement for Launch Vehicles and Propulsion Programs (NASA/HQ, 1973). Because the quantities of propellants in a Titan III E/Centaur launch (638 MT) (NASA/DOD, 1972) are about 36 percent of the Shuttle plus IUS launch (1736 MT) (NASA/JSC, 1976), the direct exhaust effluents are proportionately less. The number of people associated with the manufacture and launch of the vehicle is less and they live in different parts of the country. Accordingly, the impact of one Titan launch and, depending upon the option pursued, one or more Scout launches would be less than one Shuttle launch. The Titan would be launched from Kennedy Space Center. The Scout could be launched either from Wallops Flight Center, Va, Vandenberg Air Force Base, CA, or from the Italian Government's San Marco Platform off the coast of Kenya. The smaller effects would thus be distributed in both time and location. Secondary effects due to the ground station remain the same as for Shuttle launch since changing the launch mode would affect only the space segment of the system.

4.4.2 Noise

The noise from ELV launches is somewhat less than for the Shuttle launch, again because the expendable vehicles are significantly smaller than the Shuttle. There is no landing noise because the expended stages fall in the ocean. The noise from ground station activities is the same whether Shuttle or ELVs are used because the networks remain the same. It should be noted, however, that all launches have high noise levels and require exclusion zones to protect people from hazardous noise levels.

4.4.3 Space Quality (Space Debris)

The use of ELVs would slightly modify the accumulation of space debris. The use of any Titan vehicle would place a Titan second stage in a low Earth orbit; this stage would reenter in a period which could vary from a few weeks to decades depending upon the trajectory used. If a Titan III E/Centaur were selected, the Centaur stage would remain near Geosynchronous Equatorial Orbit in a manner similar to that of the last stage of the IUS. If a Titan 34D/IUS is selected, both of the IUS stages will remain in long-lived Earth orbits similar to those of the IUS launched by Shuttle. If a Scout were used for the research payloads, most of the components would return from low Earth orbit with the experiments. The final stage used to reach orbit and any remaining components would reenter within a short period due to the drag caused by the residual atmosphere in low Earth orbit. Only the stages and other components from the IUS or Centaur would remain in orbit for many years. The first IUS stage would traverse the region of highest collision probability and would result in a very slight increase in the collision probability of about $10^{-5}/m^2$ of collision cross-section per year (Kessler, 1981). As is the case of the IUS launched by a Shuttle (see Section 4.2.3) the probability of collision with a spacecraft in this region with a $10 m^2$ cross-section during a 10 year nominal life is about 0.001. If a Titan III E/Centaur were selected, no major debris would be left in this region. The Centaur stage would remain in a near-geosynchronous orbit where the collision probability is much lower. In all cases, the increase in collision probability due to the use of propulsion stages would be considered by NASA to be an acceptable risk in exchange for improved data relay and tracking capabilities.

4.4.4 Human Health

No source of human health hazards has been identified for normal operations of these payloads. Accidents and their consequences are discussed in Section 4.4.8.

4.4.5 Ecological Resources

The impact on ecological resources is low for launch of most spacecraft because there is little opportunity for environmental interaction. The potential for interaction comes through demand for resources to make and launch the spacecraft.

The resource and energy requirements for one Shuttle launch of the payloads are greater than for the Titan and possibly one or more Scout launches needed to provide equivalent service. Thus, it is concluded that the ELVs result in less of a burden on environmental resources than the proposed Shuttle launch. The ground station (WSGT) will remain unchanged whether ELVs or the Shuttle are selected.

4.4.6 Socioeconomic Impacts

Most of the socioeconomic impacts for use of ELVs would be the same as for the proposed launch of the payloads by the Space Shuttle. For example, the ground station changes would remain the same. The Titan vehicles used for the ELV alternative, however, are manufactured by different contractors using different labor forces. Thus a socioeconomic consequence of a shift to the Titan ELVs would be a shift in work away from the Shuttle labor force to the smaller Titan labor force. This shift would be measurable, but would not be considered significant on a national scale.

4.4.7 Resource Use

The resources required for the launch of a Titan III E/Centaur are 638 MT and for a Titan 34D/IUS are 652 MT of launch vehicle fuels and materials, none of which are recovered. The Scout needed to provide research payload launch capability if the Titan 34D/IUS is selected would require 21.5 MT of materials (NASA/DOD, 1972; Boeing, 1982). These launches represent an estimated energy requirement of 850 x 10^9kJ or about that needed for 2050 midwestern homes for one year (Rice, 1978), and about 57 percent of that used for the Shuttle. No resource implications either within or outside of the aerospace industry are forseen for the ELV launches.

4.4.8 Accidents

The accidents for unmanned ELV launches are the loss of the payloads and temporary damage to the immediate environment near the accident site. The already low probability of human fatalities would be greatly reduced by use of ELVs rather than the Shuttle. Detailed discussion of accident consequences for ELVs is available in the EIS for Launch Vehicles and Propulsion Programs (NASA/HQ, 1973). The accident consequences for the ground stations are the same whether Shuttle or ELVs are used. The effects of loss of communications capacity would also be the same as for the Shuttle.

5.0 LIST OF INDIVIDUALS AND ORGANIZATIONS CONSULTED

The individuals listed in the following table were involved in or consulted for the assessment of environmental effects in the STS-6 payloads and/or the alternative methods of accomplishing their goals.

PEOPLE INVOLVED AND CONSULTED IN SUPPORT OF THE STS-6 ENVIRONMENTAL ASSESSMENT

Name	Organization	Area of Expertise	Consulted for
Lew Andrews	NASA/Hq	Environmental/Safety Policy	Review
Richard Ott	NASA/Hq	STS Flight Assessment Manager	Review
William Bastedo	NASA/Hq	TDRSS Program	Information
F. J. Micale	Emulsion Polymers Inst. Lehigh University, PA	MLR Co-Investigator	Information
John F. Laudadio	NASA/Goddard SFC	Get-Away-Specials	Information
Bob Alexander	NASA Johnson Space	STS Safety	Information
Earl Smith	NASA/Johnson Space Center	STS Safety	Information
E. E. Rice	Battelle Columbus Labs	Environmental Assessment	Review
R. W. Earhart	Battelle Columbus Labs	Environmental Assessment	Environmental Analysis and Integration
G. A. Mihlan	Battelle Columbus Labs	Industrial Hygiene/Epidemiology	Health Effects/Guidelines
R. Smith	Battelle Columbus Labs	Environmental Chemistry/ Regulations	Chemical Effects/Guidelines
M. A. Eischen	Battelle Columbus Labs	Ecology	Ecological Effects/Guidelines
R. C. Reynolds	Battelle Columbus Labs	Astronomy	On-Orbit Debris Hazards
L. A. Miller	Battelle Columbus Labs	Environmental Assessment/ Propulsion	Review
T. M. Crabb	Battelle Columbus Labs	Aeronautical Engineer/ Environmental Assessment	Review
A. E. Tischer	Battelle Columbus Labs	Aeronautical Engineer	TDRSS Information

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TDRS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[Notice (83-27)]

National Environmental Policy Act; Finding of No Significant Impact

AGENCY: National Aeronautics and Space Administration.

ACTION: Notice of finding of no significant impact.

SUMMARY: The sixth flight of the Space Shuttle (STS-6) with a crew of four astronauts is currently scheduled for early April 1983 from the Kennedy Space Center, Florida. This flight represents the initial flight of the Shuttle Orbiter Challenger and the first use of the light-weight Solid Rocket Boosters and External Tanks. Also, STS-6 will launch the first Shuttle-transported Inertial Upper Stage (IUS). The primary purpose of the STS-6 mission is to deliver the initial Tracking and Data Relay Satellite (TDRS-A), together with the IUS which is needed to transport the TDRS-A to geosynchronous equitorial orbit from the Shuttle's low orbit. Secondary STS-6 mission objectives are: (1) To carry and operate seven research payloads which will be returned to Earth at Edwards Air Force Base, California, upon conclusion of the flight; and (2) to conduct tests and collect technical information on Shuttle vehicle systems and supporting equipment.

The Tracking and Data Relay Satellite will initiate a major improvement in NASA's tracking and data relay capabilities. The improved capabilities are needed for NASA and other government spacecraft operations, and the support of future manned mission activity. Three TDRS geosynchronous orbit satellites are planned to be launched by 1984 to support NASA's Tracking and Data Relay Satellite System (TDRSS). Once operational with two TDRSS satellites in position (the third is an on-orbit spare). The TDRSS will significantly increase the time available for transmission of data to and from orbiting satellites/spacecraft and the ground. The time available is increased because of the satellite/spacecraft transmission of data directly to the orbiting TDRS and subsequent relay to one ground station located at White Sands, New Mexico.This improved data transmission capability will increase the value of many spacecraft, as well as providing increased safety for the Space Shuttle crew. The transition to TDRSS will permit NASA to phase out ten existing ground stations around the world. The estimated net change in employment at NASA ground stations is a decrease of approximately 100 employees.

The TDRSS is being developed for NASA under a lease arrangement by the Space Communications Company (Spacecom), a jointly-owned subsidiary of Western Union Space Company, Inc., Fairchild Industries, and Continental Telephone Company. Under this arrangement, NASA will lease the service from Spacecom, who purchases the spacecraft from the manufacturers and Space Transportation System (STS) launch services from NASA.

The TDRS spacecraft is manufactured by TRW, Inc., and the Boeing Company builds the IUS. The masses of the TDRS and IUS are approximately 2,300 kg and 12,300 kg, respectively. When integrated and installed in the Shuttle's payload bay, they occupy 63 m^3, or about 20 percent of the total volume available. Two solid rocket motors are used by the IUS. They contain a total of approximately 12,500 kg of hydroxyl-terminated polybutadiene (HTPB) based solid propellant. The IUS also carries 112 kg of hydrazine propellant for reaction control. The TDRS carries 605 kg of hydrazine propellant to provide

attitude control and station keeping for its planned 10-year life on orbit. The transport of these propellants on the Shuttle is the largest payload contribution to the risk of possible loss of the Shuttle vehicle and crew as well as other adverse environmental effects. Rigorous NASA and Department of Defense (DOD) safety procedures are applied to the STS and its payloads to preclude risk of catastrophic accidents.

Seven research payloads are classified as either Get-Away Special (GAS) payloads or as Mid-Deck payloads. Three small self-contained GAS payloads will be located in the Shuttle's payload bay. The payloads do not use Shuttle utilities (e.g.. power) and the only attention required by the Shuttle's crew is to turn them on and off by remote control. GAS payloads are being flown on the Shuttle as part of a NASA program intended to encourage new uses of space. Payloads are currently limited to a volume of 0.15 m^3 or 5 ft^3. The three GAS payloads planned for STS–6 are: (1) Crystal Growth of Artificial Snow, (2) Seed Experiment Payloads, and (3) Project Scenic Fast.

The *Crystal Growth of Artificial Snow* experiment is sponsored by the Asahi Shimbum Company of Japan and will examine growth of snowflakes under zero-gravity conditions. The Asahi Shimbum Company is a major Japanese newspaper which is sponsoring this experiment as the result of a competition for readers who proposed experiments which could be flown on the Shuttle within the constraints for GAS payloads.

The *Seed Experiment Payload* is sponsored by the George W. Park Seed Company to expose packaged seeds of many common vegetables and flowers to the space environment. After return to Earth, tests for seed coat integrity, germination, dormancy, increased mutation rate, and vigor or performance will indicate the best packaging method for space transportation of seeds. The test-flown seeds will be compared with control seeds held at the Kennedy Space Center and at the company.

Project Scenic Fast is sponsored by the United States Air Force Academy and contains six different student experiments. These are: (a) *Metal Beam Joiner* to demonstrate the soldering of two brass beams under zero-gravity conditions; (b) *Immiscible Alloy* to determiune whether tin spiked with gallium (23 grams) will exhibit improved conductivity when the two elements are melted together in a zero-gravity environment; (c) *Foam Metal* will produce a sample of lead foamed by sodium bicarbonate in an evacuated glass tube; (d) *Crystal Purification* will test the effectiveness of the zone refining method of purification in zero-gravity using an 8-cm rod of lead-tin solder sealed in a glass tube; (e) *Electroplating* will determine how evenly copper plating is deposited on a copper rod in zero-gravity; and (f) *Effects on a Micro-organism* will determine the effects of weightlessness and space radiation on the development of non-pathogenic micro-organisms (Sarcena Lutea).

Four Mid-Deck research payloads will be located within the crew cabin. These payloads use Shuttle utilities and require crew attention while the payload is active. These payloads, which are either sponsored or cosponsored by NASA, are the Monodisperse Latex Reactor (MLR), the Continuous Flow Electrophosesis System (CFES), the Night-Day Optical Sensor of Lightning (NOSL), and Shuttle Glow.

The *Monodisperse Latex Reactor* (MLR) will carry about 400 ml of a water-latex solution. The purpose of this experiment is to effect this solution so that small, very uniformly spherical particles of latex are formed in the zero-gravity environment. These spheres will be used later as laboratory standard to measure pore size in membranes. The understanding of pore size effects on the permeability of membranes is expected to lead to economic applications, since many valuable separations of mixtures and solutions can be accomplished with a better understanding of membrane properties.

The *Continuous Flow Electrophoresis System* (CFES) has as its objective the determination of the effectiveness of electrophoresis methods in zero-gravity. Electrophoresis techniques are used to separate and concentrate biochemical compounds by utilizing slight differences in the compounds' electrical properties. The CFES experiment is intended to provide information about the feasibility of developing a pharmaceutical manufacturing and purification system.

The *Night-Day Optical Sensor of Lightning* (NOSL) is designed to observe and record data from electrical discharges in the atmosphere, especially thunderstorms. The information is expected to lead to a better understanding of electrical processes in storms and to prediction of their effects.

The *Shuttle Glow* experiment is designed to obtain information on the glow which surrounds the Shuttle while in orbit. This glow could interfere with sensitive optical instruments such as telescopes, which will be flown on future Shuttle missions. It is currently uncertain whether the glow is due to the residual atmosphere, or to offgasing from the Shuttle, or to a combination of these possibilities. The information to be gathered will assist in determining the cause of this glow and may lead to a method of controlling the glow.

The seven basic scientific payloads (GAS and Mid-Deck) to be flown on STS–6 have been determined not to be hazardous, and will not have any impact upon the environment.

STS–6 also will perform various development tests (e.g., space suits). The major purpose of these tests is to provide information for use by the Space Shuttle Program, and is not directly related to the payloads previously discussed. The tests will have no environmental impact.

Possible alternatives to the Shuttle-integrated payloads on STS–6 (the proposed action) are: (1) No Action and (2) Use of Expendable Launch Vehicles (ELV's).

The No Action alternative is defined as continuing and possibly expending the current low capability tracking and data reception methods using existing or near NASA ground stations throughout the world. Ten existing ground stations, requiring additional NASA employment, would need to be retained to maintain the coverage for spacecraft at the current 15 percent level. Additional ground stations would be needed to provide the 85 percent coverage level to be initiated by the proposed action. Since NASA is presently unable to provide coverage in many remote locations (over oceans) the potential to achieve near world-wide coverage of spacecraft with this method would not be practical. The research experiments could not be accomplished under the No Action alternative. There is no known way to conduct experiments in the terrestrial environment requiring more than very short periods (2–5 minutes) of weightlessness. The NOSL requires the synoptic view of the Earth which can only be obtained from orbit. The Shuttle Glow experiment is specific to the Shuttle. Thus, the No Action alternative implies higher NASA ground station costs for a limited capability tracking and data acquisition network, and no benefits from the proposed research experiments.

For the Expendable Launch Vehicle (ELV) alternative, the TDRS would be flown on either of two Titan vehicle configurations. With a few minor modifications, the TDRS could be flown on a Titan IIIE/Centaur vehicle. This particular configuration is no longer in production, having been phased-out in the 1970's. With some extensive modifications to the TDRS, which would have to be reduced in mass by 20 percent, a spacecraft with less capability could be flown on a Titan 34D/IUS vehicle. In either case, substantial additional funding would be required to use either of these vehicles. Use of the Space Shuttle, however, provides an opportunity to check the satellite while it is still in Low Earth Orbit. If it cannot be repaired in orbit, it can be returned to Earth, repaired, and launched again on another flight. ELV's cannot perform this function. While the research payloads have not been designed for use on an ELV or sounding rocket, conceptually, they can be adapted and flown. The Shuttle, however, provides the user with lower costs and a safer return of the experiment to earth. The ELV would either be the Titan used for the TDRS, or a small ELV such as the Scout. In either case, the vehicle with a reentry and recovery system would be more expensive than if flown on the STS. Given current funding trends, it is doubtful that many of the experiments would be funded if the Shuttle were not available. There are also strong indications that if any of the experiments lead to space-manufactured products, they would be economical only if the Shuttle's return capability is available. Thus, while there are possible alternatives for the proposed action of the TDRS launch on the Shuttle, the alternatives for supporting the research payloads are questionable from either the technical or economic grounds.

For the proposed action, the only measurable long-term adverse environmental impact from the normal placement of these payloads is the addition of two expended solid rocket motors on the IUS, and the utlimately abandoned TDRS to an already large population, human-made space debris. The major concern associated with this debris is an increasing probability of collision with spacecraft. While the current debris accumulation poses little threat to the terrestrial environment, there is a low probability of a collision with an active spacecraft. This collision would likely destroy the spacecraft with its fragments adding to the long-term debris population. If the spacecraft were manned, it is possible that a direct hit by debris would result in the loss of life.

If the TDRS spacecraft were launch by a Titan ELV, the Titan Core II stage would also become part of the space debris population in addition to the spent upper stages. For either alternative, the potential collision risk from their addition to the space debris population is currently minimal. The net reduction in ground station employment of about 100 is not considered to be a significant adverse socioeconomic impact.

For both TDRS placement alternatives, there is a low probability of a catastrophic accident caused by either the major payload or by the launch vehicle. NASA and DOD safety procedures for design and operations will eliminate most of the risk of payload-caused accidents. In the case of the Shuttle, such an accident would very likely result in loss of the crew's lives. The Titan is unmanned. Accident consequences have been examined and have been determined to result in only local and temporary effects to the environment. Launch system accidents and detailed descriptions of their potential consequences are provided in the final Enviromental Impact Statements for the Space Shuttle Program and for the Expendable Launch Vehicle Program. The STS–6 payload contribution to potential consequences is considered to be very small when compared to the launch vehicle itself.

The research experiments are intended to be returned to the Earth and will have no interaction with the environment. These experiments have undergone safety reviews to provide as much assurance as possible that both the experiments and their ancillary equipment (such as batteries) cannot fail in a manner which would result in a hazard to the Shuttle mission. No synergistic hazards have been found for these payloads.

For the proposed action and alternatives, ground-based installations are needed. The construction operation and maintenance of these installations represents most of the direct impact on the human environment. For launch of TDRS by either the Shuttle or Titan, the ground-based installation is the same. For the No Action alternative, many additional stations would be needed to provide coverage equivalent to the TDRSS. Resource use would be the lowest for launch of the payloads on ELV's , and the all ground-based system would be the highest.

The short-term temporary environmental impact of the ELV launches would be less than one Space Shuttle launch in terms of noise and rocket-exhaust effluents. For the No Action alternative, the ground-based tracking and data relay system would have a larger impact on the terrestrial environment than a space-based system. This increased impact, however, would be dispresed geographically.

The conclusion of all analyses is that the environmental effects of the proposed action are not significant.

EFFECTIVE DATE: April 4, 1983.

ADDRESS: National Aeronautics and Space Administration, Code MCB–7, Washington, D.C. 20546.

FOR FURTHER INFORMATION CONTACT: Mr. Richard H. Ott, (202) 755–2354.

SUPPLEMENTARY INFORMATION: The environmental assessment for this proposed project was completed by the National Aeronautcis and Space Administration in January 1983.

Conclusion: The launch of STS–6 payloads will not result in any significant adverse environemntal impacts. No environmental impact statement is required for this launch.

March 30, 1983.

Ann P. Bradley,

Deputy Associate Administrator for Management.

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